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AGRICULTURAL RESEARCH SERVICE

PROGRESS REPORT 2000

GRAIN MARKETING AND PRODUCTION RESEARCH CENTER

1515 College Avenue
Manhattan, Kansas 66502

Telephone - 1-800-627-0388   FAX - (785) 776-2789
Web Site Address: http://www.usgmrl.ksu.edu

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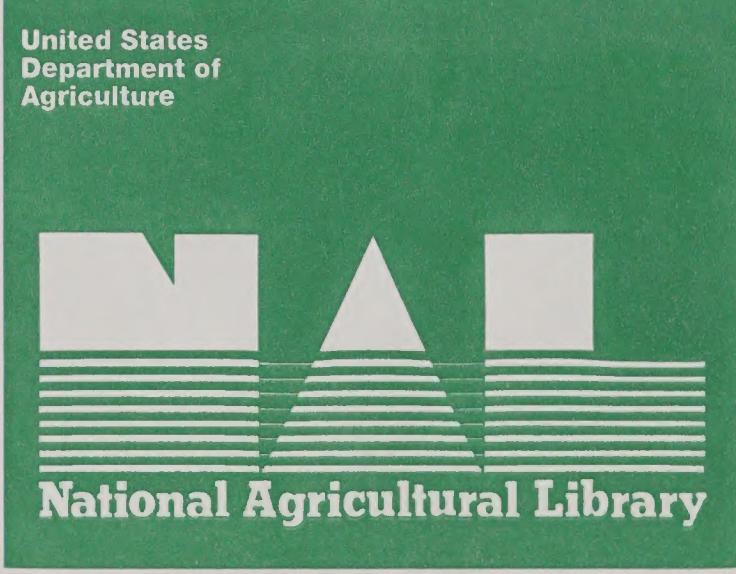
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WELCOME TO GMPRC

Since its establishment in 1970, the Agricultural Research Service's Grain Marketing and Production Research Center (GMPRC) has been the U.S. Department of Agriculture's main facility for conducting research on measuring and controlling the quality of cereal grains throughout the grain industry.

The Center focuses on solving food and agricultural problems in grain production and marketing, alfalfa production, and wind erosion control. Our research emphasizes maximal nutritional value, consumer acceptance, and end-use performance while conserving resources and maintaining soundness and overall quality during handling, conditioning, and storage.

Located in Manhattan, Kansas, GMPRC is situated in the heart of the Great Plains, which includes thirteen states, that produce more than 2/3 of all U.S. wheat, corn, alfalfa, sorghum, and soybeans. Operating from a 60,000 square foot facility, and the nation's only 50,000 bushel (700 metric ton) capacity research grain elevator, the Center is composed of five research units:

- BIOLOGICAL
- ENGINEERING
- GRAIN QUALITY AND STRUCTURE
- PLANT SCIENCE AND ENTOMOLOGY
- WIND EROSION

Our VISION is to be **"The Customer's Choice in grain, alfalfa, and wind erosion science and technology"** and we welcome the opportunity to serve all segments of the grain industry from producers to consumers.
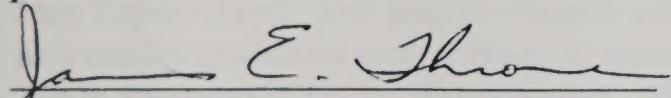
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Biological Research Unit
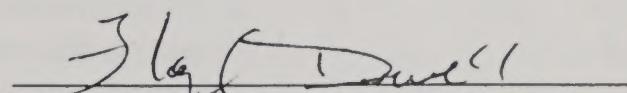
Dr. Floyd E. Dowell, Research Leader
Engineering Research Unit
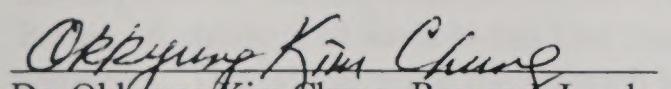
Dr. Okkyung Kim Chung, Research Leader
Grain Quality and Structure Research Unit
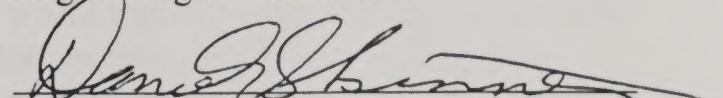
Dr. Daniel Z. Skinner, Acting Research Leader
Plant Science & Entomology Research Unit
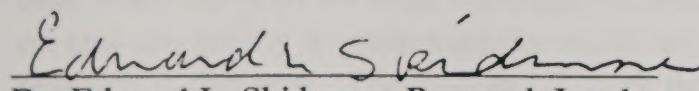
Dr. Edward L. Skidmore, Research Leader
Wind Erosion Research Unit
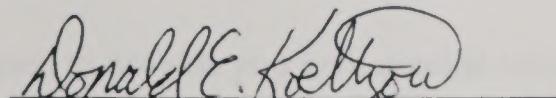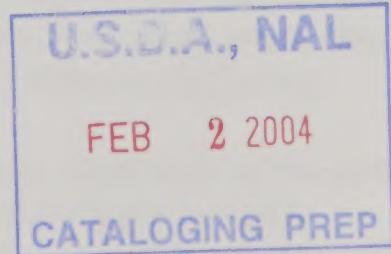
Dr. Donald E. Koeltzow
Center Director

INTERACTIONS WITH KANSAS STATE UNIVERSITY

Kansas State University (KSU) has a world renowned reputation in many fields; however, they have an exceptionally strong program in agriculture. GMPRC maintains a very close working relationship with KSU and the Kansas Agricultural Experiment Station and Cooperative Extension Service. Two of the GMPRC research units, namely Plant Science and Entomology and Wind Erosion, are housed on the KSU campus and the Northeast Area Extension Offices are housed in the GMPRC facility. GMPRC scientists enjoy a very close working relationship with scientists at KSU. A majority of the GMPRC scientists have adjunct faculty positions and, as a result, approximately 40 undergraduate and graduate students conduct research at GMPRC each year.

A Special Note to Our Customers

A number of excellent changes have taken place at the Center during the year 2000. **1) New Heating and Cooling Facilities Added.** One of the most visible is that we have added extra space to house the new boilers and chillers that heat and cool our main facility. These are much more energy efficient than the old ones and they are part of a complete renovation program for this facility. **2) Two New Research Scientist Positions Added.** In addition, as a result of strong customer input, we have received additional funding for two new research positions. The objective for one of these positions will be to develop new uses for grain sorghum and the objective for the other position will be to establish a DNA molecular marker analysis program for wheat. We will be inviting each of you to attend an open house at our facility once the weather warms up this spring.

On a sadder note, we also have lost two research scientist positions during this past year. **1) The Biological Research Unit (BRU) decreased from 13 to 12 research scientists.** Dr. Alan Dowdy accepted a promotion with the Animal and Plant Health Inspection Service. His research area centered on the development of insect pest control methods for use in production and warehouse facilities that will be able to replace methyl bromide. Due to lack of funds, Dr. Dowdy was not replaced and the Unit's ability to conduct research in this very important area was decreased significantly. The BRU is the national center of research work on insect problems in stored grain and processed cereal products and it also is the largest center for stored-product insect pest research in the world. Only a very few scientists outside of this unit work on these problems. This decrease in research capabilities is occurring at the same time that many of the fumigants and insecticides used for insect control in food and food production facilities are being lost.

2) The Engineering Research Unit decreased from 5 to 4 research scientists. In 1999, Dr. Inna Zayas retired. Her area of research expertise centered on the development of image analysis as a quality prediction tool. Efforts to replace her are still continuing at this time. In 2000, Dr. James Steele and Charles Martin retired. Their research programs focused on the development of analytical tools and methods for grain quality measurement. They were instrumental in the development of the single kernel hardness tester for wheat that is currently being marketed by Perten. A shortage of funds in this Unit mandates that we replace only one of these two engineers. This will decrease the research potential of this Unit by 20% which reduces their ability to develop quality measurement tools and grain handling techniques. This is occurring at a time when the need for such tools and techniques is at an all-time high due to increased emphasis on end-use quality in grain markets world-wide. Very few scientists outside of ARS are doing research in this area. The amount of work that exists for these four individuals in a country that, in 1999, produced over 15 billion bushels of grain worth just under $37 billion is staggering.

This Progress Report is designed to provide you with specific information about each of the active research projects at GMPRC. Three types of projects are described. Each major research project in the Agricultural Research Service, including those at GMPRC, is identified by a number

from the Current Research Information System (CRIS). In addition, we frequently develop Specific Cooperative Agreements (SCAs) or Cooperative Research and Development Agreements (CRADAs) with other groups such as universities, other federal agencies, or private companies. These agreements describe cooperative research projects and they are usually associated with specific CRIS projects.

The information in this Progress Report is organized by Research Unit. The CRIS projects for each Research Unit are described in numerical order and the active SCAs and CRADAs are listed under each appropriate CRIS project. A complete Table of Contents is provided on the following pages.

For each project described, we have provided a statement of the problem that we are trying to solve, the goals and objectives for this particular research activity, the results obtained during 2000, and our future goals for this research activity. We also have included a list of publications along with a contact person if the reader has additional questions or needs more detailed information on a project. We certainly appreciate your comments and suggestions concerning ways that we can improve this report and we encourage you to continue to send your comments via mail, telephone, FAX, or email to:

Dr. Donald E. Koeltzow, Director
USDA-ARS-GMPRC
1515 College Avenue
Manhattan, KS 66502

Telephone: 1-800-627-0388 or 785-776-2701
FAX: 785-776-2789

email: dek@gmprc.ksu.edu

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BIOLOGICAL RESEARCH UNIT

The mission of the Biological Research Unit is to develop new and improved methods, approaches and strategies for the management of insect pests that attack grain. In order to decrease the levels of chemical pesticides used to protect our food supply, safer more effective alternatives must be developed. In 2000, each of the specific research projects for this Unit were reviewed and evaluated using customer input. The revised projects include:

CRIS - 5430-43000-018-00D Monitoring, Prevention, and Control Strategies for Stored-Product Insects

CRIS - 5430-43000-019-00D Functional Genomic-Based Management of Stored-Product Insect Pests

CRIS - 5430-43000-020-00D Biological Control of Stored-Product Insects

CRIS - 5430-43000-021-00D Decision-Making Tools for Integrated Pest Management of Stored-Product Insects

CRIS - 0500-00044-004-00D Development of a Stored Wheat Area-Wide Management Program in Kansas and Oklahoma

CRIS 5430-43000-018-00D

Monitoring, Prevention, and Control Strategies for Stored-Product Insects

Project Leader: M. Mullen   **Investigators:** M. Mullen, F. Arthur, and J. Campbell

Full-Time Scientist Equivalents (SYs): 3.0   **Net Funding to Location per Year:** $ 603,716

Start Date: 10/28/99   **Term Date:** 10/27/04

Problem: Insect pests can contaminate and destroy stored food products which can decrease food quality and destroy customer acceptance. World-wide estimates of product losses due to this pest activity range from 10% to 15% in temperate climates and to more than 30% in sub-tropical and tropical climates. In the U.S., cost estimates for this damage range from 1.2 to 2.4 billion dollars per year.

Effective, economical, and environmentally friendly management of pests in food processing and storage facilities requires the development of new monitoring and control tactics. Monitoring of insect pests in storage and manufacturing facilities will lead to early detection of insect pests so that they can be controlled more easily with fewer chemicals. In addition, information on the distribution of pest populations can allow for more targeted control. Tools such as baited traps and other monitoring techniques need to be developed. Implementation and interpretation of monitoring programs requires an understanding of insect pest behavior. With fewer chemicals available, it also is necessary to identify the factors that can improve the effectiveness of remaining pesticides and to develop new control strategies.

Objectives: The objectives of this project are to develop monitoring and control strategies for stored-product insect pests in and around storage and processing facilities. Included are the development of effective traps baited with chemical attractants, exploitation of insect behavior and ecology to increase the effectiveness of monitoring and control practices, ecologically sound chemical control procedures, non-chemical control methods, and insect-resistant packaging. The physical and biological factors that can affect pesticide efficacy will be determined and new insect growth regulators, inert dusts, and natural products will be examined as alternatives to conventional pesticides. Non-chemical procedures such as the use of aeration for raw grain and heat alone or in combination with diatomaceous earth for processing facilities will be examined for their effectiveness in controlling insect pests.

Results and Impact:

1. Temperature and Relative Humidity Impact Efficacy of Diatomaceous Earth.
Diatomaceous earth (DE) is a low-toxicity, natural product registered to control insect pests in stored products. When red flour beetles and confused flour beetles are exposed to diatomaceous earth, mortality of both species increases with temperature and decreases with relative humidity.

In addition, the confused flour beetle is more tolerant to DE than the red flour beetle, and longer exposure intervals may be required to eliminate populations of the confused flour beetle. Seasonal variation within a storage facility, the target pest species, and the presence of food material must be taken into account when using DE to control flour beetles in mills and food warehouses.

2. Pest Resistant Package Development. Losses in packaged processed foods are significant because these products have undergone all of the expenses associated with growing, harvesting, processing, storage, transportation, and packaging. Suggestions were made to improve package closures for several food producers. A pouch package with a zipper seal and high resistance to infestation by stored-product pests was developed. However, the configuration of this new package made it difficult to stock and display. As a result, the development of more insect resistant, traditional packaging such as paperboard cartons is being studied. Odor barriers were found to effectively prevent infestation, however, even minute holes or flaws in the package will attract insects and could lead to infestation.

3. Monitoring Stored-Product Pest Movement Patterns Outside Food Processing Facilities. Insect populations outside of food processing and storage facilities are potentially important sources of infestation. Pest populations surrounding a pet food processing plant were monitored using a variety of techniques. Results indicated that both warehouse beetles and Indianmeal moths were present in large numbers outside the plant, that their numbers varied with time and location around the plant, and that the insects were highly mobile.

Goals for 2001 and 2002:

Specific tasks in 2001 will be to:

1. Develop a mapping procedure to estimate pest populations in processing facilities, warehouses, and grocery outlets and to measure insect movement within these facilities.

2. Continue to cooperate with the food packaging industry to develop insect-resistant packaging and identify the importance of odor in insect-resistant packaging.

3. Identify specific physical and biological factors that determine the effectiveness of diatomaceous earth in raw grain, indoor mills, and warehouses.

4. Continue research on the distribution of stored-product pests inside and outside of food processing facilities and determine the movement patterns and behaviors that influence insect distribution.

5. Assess the potential of biological control agents such as nematodes to control stored product pests inside and outside of facilities.

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6. Develop a chemical lure (pheromone) for the sawtoothed grain beetle.

Specific tasks in 2002 will be to:

1. Conduct additional modeling studies to predict how quickly aeration can cool grains stored in different regions of the United States and predict the impact of aeration on insect populations.

2. Identify and evaluate new, more effective, and environmentally friendly insecticides that can replace current products that are being phased out of production and use.

3. Continue to study the distribution of insects and movement patterns inside and outside of food processing facilities.

4. Continue to develop and improve insect-resistant package designs.

5. Continue to assess the potential of biological control agents such as nematodes to control stored product pests inside and outside of facilities.

Summary of 2000 Publications/Patents:

01. Arthur, F.H. Impact of accumulated food on survival of *Tribolium castaneum* on concrete treated with cyfluthrin wettable powder. Journal of Stored Products Research. 2000. v.36. p.15-23.

02. Arthur, F.H. Toxicity of diatomaceous earth to red flour beetles and confused flour beetles: effects of temperature and relative humidity. Journal of Economic Entomology. 2000. v.93(2). p.526-532.

03. Arthur, F.H. Impact of food source on survival of red flour beetles and confused flour beetles (Coleoptera: Tenebrionidae) exposed to diatomaceous earth. Journal of Economic Entomology. 2000. v. 93 p. 1347-1356.

04. Arthur, F.H. and Flinn, P.W. Aeration management for stored Hard Red Winter wheat: simulated impact on rusty grain beetle (Coleoptera: Cucujidae) populations. Journal of Economic Entomology. 2000. v. 93 p. 1364-1372.

05. Mullen, M.A. and Mowery, S.V. The use of insect resistant packaging to minimize insect infestation in processed food products. In Proceedings of the 2000 Food Processing Pest Management Workshop (Oklahoma State University), p. 55-64. Oklahoma City, OK.

06. Mullen, M.A. and Pederson, J.R. Sanitation and exclusion. In Alternatives to Pesticides in Stored-Product IPM. Bh Subramanyam and D. W. Hagstrum, Editors. Kluwer Acad. Pub. Norwell, MA. 2000. p. 29-50.

07. Reed, C. and Arthur, F.H. Aeration. In <u>Alternatives to Pesticides in Stored-Product IPM</u>. BH. Subramanyam and D. W. Hagstrum, Editors. Kluwer Academic Publishers, Boston, MA. 2000. p. 51-72.

08. Zettler, J. L. and Arthur, F.H. Chemical control of stored product insects with fumigants and residual treatments. Crop Protection. 2000. v. 19 p. 577-582.

For More Information on this Project Contact:

Dr. Mike Mullen
Telephone - 1-800-627-0388 or (786) 776-2782
FAX - (785) 776-2792
email - mullen@gmprc.ksu.edu

CRIS 5430-43000-018-00D - Specific Cooperative Agreement

Monitoring Insect Population Dynamics and Movement Using Molecular Markers

Investigators: F. Arthur, R. Beeman, and K. Zhu[1]

Start Date: 06/01/98   **Term Date:** 06/01/02

Problem: Insect monitoring systems allow us to determine where stored-product insects are located within a facility but do not indicate the origin of an infestation. It is important to know where the infestation started so that corrective actions can be taken at the appropriate place in the marketing system. Genetic markers are being developed to allow us to identify the origin of an insect and its susceptibility to insecticides used in the food processing industry. This technology will allow us to determine where an insect infestation originated and the appropriate insecticide to use if necessary.

Objectives: The genetic basis of phosphine resistance in the lesser grain borer will be examined, and DNA markers will be developed that will eventually allow us to identify where an infestation originated as well as detect possible insecticide resistance issues before a control treatment is applied. This information is important in the establishment of effective integrated pest management programs.

Results: Two strains of lesser grain borer with very high resistance to phosphine have been acquired from Australia and India. Genetic analysis of these resistances has been initiated. Current efforts are focused on investigation of a component of one enzyme (cytochrome C oxidase) as the potential source of this resistance.

Goals for 2001:

During 2001, we will complete the segregation of phosphine resistance genes from highly resistant strains, and will attempt to identify molecular markers closely linked to these genes. Possible involvement of cytochrome C oxidase in the resistance mechanisms will be assessed. Eventually, we hope to use resistance-linked DNA markers to monitor the spread of resistance in natural populations.

Publications: None at this time.

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[1]Department of Entomology, Kansas State University

For More Information on this Project Contact:

Dr. Frank Arthur
Telephone - 1-800-627-0388 or (785) 776-2783
FAX - (785) 776-2792
email - arthur@gmprc.ksu.edu

CRIS 5430-43000-018-00D - Cooperative Research and Development Agreement

Monitoring and Control Strategies for Stored-Product Insects - Pet Food Packaging

Investigators: M. Mullen and S. Wiles[1]

Start Date: 03/31/97   **Term Date:** 03/31/02

Cooperator: Ralston-Purina Company, Inc., St. Louis, Missouri

Problem: Pet foods can serve as a source of insect infestation in the food distribution chain. Improved packaging for dry pet foods is needed in order to reduce infestation potential.

Objectives: The objective for this project is the development of pet food packaging that is more resistant to insect infestation while in storage and in retail stores.

Results: Pet food packaging has been shifting to the use of re-sealable plastic pouch packs. Generally, this type of packaging has greatly reduced losses due to insect contamination. However, because of their construction, these packages are more difficult to display in the retail stores. Research is focused on re-examining the use of paperboard cartons to improve resistance and determining if the same product produced and packaged in different locations varies in susceptibility to selected stored-product insects. The completion of these studies will establish base line data with which to compare future package improvements.

Goals for 2001 and 2002:

Specific tasks in 2001 will be to continue work on testing new package designs and materials.

Specific tasks in 2002 will be to, in cooperation with Ralston Purina, examine new packaging and make recommendations for improvement in insect resistance.

Publications: None at this time.

For More Information on this Project Contact:

> Dr. Mike Mullen
> Telephone - 1-800-627-0388 or (785) 776-2782
> FAX - (785) 776-2792
> email - mullen@gmprc.ksu.edu

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[1]Ralston Purina Company, St. Louis, MO

CRIS 5430-43000-018-00D - Cooperative Research and Development Agreement

Monitoring and Control Strategies for Stored-Product Insects - Food Packaging Materials

Investigators: M. Mullen and T. Z. Fu[1]

Start Date: 10/01/97   **Term Date:** 10/01/02

Cooperator: International Paper, Loveland, Ohio

Problem: During the movement from the manufacturer to the consumer, food products can become infested with insect pests. More importantly, contaminated products can lead to a loss of customer confidence. Improved control methodologies are needed to decrease the infestation potential to a minimum.

Objectives: The goal for this project has been expanded to include the development of improved seals and closures in addition to investigating potential insect repellants that can be incorporated into packaging materials and determining their effectiveness.

Results and Impact: In the past year tests on improved seals for pet food packaging have been conducted in cooperation with a pet food manufacturer. It was determined that the traditional package provided little or no resistance to infestation. By changing the construction of the seals and closures, resistance to infestation was increased.

Goals for 2001 and 2002:

Specific tasks in 2001 will be to evaluate new compounds for repellent qualities and redesign and test package closures.

Specific tasks in 2002 will be to continue work on the development of repellents and seals.

Publications: None at this time.

For More Information on this Project Contact:

> Dr. Mike Mullen
> Telephone - 1-800-627-0388 or (785) 776-2782
> FAX - (785) 776-2792
> email - mullen@gmprc.ksu.edu

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[1]International Paper, Loveland, OH

CRIS 5430-43000-018-00D - Cooperative Research and Development Agreement

Physiological Effects of Insect Growth Regulators on Stored-Product Insects

Investigators: F. Arthur and S. Ramaswamy[1]

Start Date: 08/01/00   **Term Date:** 07/31/02

Cooperator: Kansas State University

Problem: During the movement from the manufacturer to the consumer, food products can become infested with insect pests. More importantly, contaminated products can lead to a loss of customer confidence. Improved control methodologies are needed to decrease the infestation potential to a minimum.

Objectives: Organophosphate insecticides are being removed from use as grain protectants due to new regulatory requirements. Insect growth regulators are potential replacements, but additional data are needed regarding the effects of these chemicals, particularly at sub-lethal concentrations.

Results and Impact: This is a new project with no progress to date.

Goals for 2001 and 2002:

Specific tasks in 2001 will be to initiate preliminary studies using insect growth regulators to control representative stored-product insect species.

Specific tasks in 2002 will be to conduct advanced studies with sub-lethal concentrations.

Publications: None at this time

For More Information on this project contact:

> Dr. Frank Arthur
> Telephone 1-800-627-0388 or (785) 776-2783
> Fax (785)776-2792
> email: arthur@gmprc.ksu.edu

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[1]Department of Entomology, Kansas State University

CRIS 5430-43000-018-00D - Cooperative Research and Development Agreement

Replacements for Organophosphates as Stored-Grain Protectants for Use in Food Processing

Investigators: F. Arthur and T. Phillips[1]

Start Date: 12/01/00   **Term Date:** 11/30/02

Cooperator: Oklahoma State University, Stillwater, Oklahoma

Problem: Several insecticides are currently registered that can replace older organophosphates. Data are needed for the performance of these chemicals under different environmental conditions.

Objectives: The goal of this project is to determine the performance of potential replacements for organophosphate insecticides under different environmental conditions.

Results and Impact: This is a new project, with no progress to date.

Goals for 2001 and 2002:

Specific tasks in 2001 will be to initiate preliminary studies of the effectiveness of proposed replacement insecticides.

Specific tasks in 2002 will be to conduct advanced studies under different environmental conditions.

Publications: None at this time.

For More Information on this Project Contact:

> Dr. Frank Arthur
> Telephone 1-800-627-0388 or (785) 776-2783
> Fax (785)776-2792
> email: arthur@gmprc.ksu.edu

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[1]Oklahoma State University, Stillwater, OK

CRIS 5430-43000-019-00D

Functional Genomics-Based Management of Stored-Product Insects

Project Leader: K. Kramer   **Investigators:** K. Kramer, R. Beeman, and J. Baker

Full-Time Scientist Equivalents (SYs): 3.0   **Net Funding to Location per Year:** $ 720,130

Start Date: 10/27/99   **Term Date:** 10/26/04

Problem: Stored-product insects cause numerous problems throughout grain production and marketing channels, which relate to the conservation, production, harvesting, storage, marketing, and utilization of wheat, sorghum, corn, rice, barley, oats, soybeans, and triticale. These pests are detrimental to commodity nutritional value, consumer acceptance, and end-use performance. As value is added to these commodities, losses become even more significant. Because export markets depend on high quality products, any reduction in grain quality will result in loss of economic benefits to the American farmer and processor. Novel pest management practices are needed to prevent spoilage or contamination by post-harvest pests and pathogens and to conserve resources and maintain overall commodity quality during handling, conditioning, storage, and processing.

Objectives: The goal of this project is to develop ecologically-sound pest management technologies to replace or reduce the use of traditional pesticides. Novel control techniques that offer an alternative to environmentally hazardous chemical insecticides and that can significantly reduce these commodity losses during storage are being developed based on a knowledge of insect genetics, physiology, biochemistry, toxicology, and molecular biology. Specifically, we are characterizing the physiological and genetic processes in stored-product insects which can be manipulated in order to develop control tactics using biopesticides and natural enemies. We also are developing techniques for genetic manipulation of insects and devising methods for managing pesticide resistance and enhancing the effectiveness of beneficial insects. In addition, we are developing the techniques to increase the expression and activity of biopesticides in transgenic plants.

Results and Impact:

1. Antibodies Provide Important Information About the Immune System of the Indianmeal Moth. The Indianmeal moth is the most damaging insect pest of stored products in the U.S. Virtually nothing is known of the immune response system in larvae of this insect pest. In an initial attempt to study this complex system, plasma obtained from the larval stage of the Indianmeal moth was tested with antibodies that had been developed against nine different proteins from the tobacco hornworm that are involved in protecting the hornworm from attack by bacteria and fungi. Positive responses were obtained with five of the nine antibodies indicating that the larvae of the Indianmeal moth have five of the same immuno proteins that are found in the tobacco hornworm. Since the function of these proteins in the hornworm is partially understood,

this provides important information about the immune system of the Indianmeal moth. These initial positive results provide an excellent basis for unraveling the physiological and biochemical events involved in the immune response of the Indianmeal moth. Such information may be used to inhibit its immune system and make this insect pest more susceptible to biological control using various bacteria and fungi.

2. Indianmeal Moth Immune System Produces Antimicrobial Peptides and Recognition Proteins. One general aspect of many insect immune systems is the production of small peptides when attacked by microorganisms such as bacteria and fungi. These peptides have antimicrobial activity and help defend the insect against the onset of disease. Analysis of the plasma from Indianmeal moth larvae showed the presence of eight antimicrobial peptides when under fungal attack compared with none in controls that were not exposed to fungi. An additional protein that was capable of recognizing the surface of the attacking fungus was also identified and partially characterized. Recognition of a foreign invader is a vital component of any immune defense system. Knowledge of how this system works to protect the Indianmeal moth may provide important tools for biological control of this pest insect.

3. Detection of Insect Fragments in Flour by Near-Infrared Spectroscopy. The presence of insect fragments in flour is a major problem for the milling industry. Current methods for detecting these fragments are laborious and involve extraction and microscopic evaluation. We have successfully demonstrated the use of near infrared spectroscopy in the detection of insect fragments in wheat flour. Our results will provide the basis for an on-line, automated system for fragment detection and should help maintain high quality food products for the consumer.

4. Pea Flour Kills Grain Weevils But Is Not Toxic to Beneficial Insects. Cooperative research between BRU scientists and scientists at Agriculture Canada have demonstrated that pea flour applied to whole wheat is very toxic to rice weevils and several other grain insects. However, results obtained with several types of bioassays indicated that the behavior and effectiveness of a common parasitic wasp associated with the weevils, was not affected by the pea flour treatments. The mechanism of toxicity of the pea flour against the weevils is not known with certainty, but our evidence indicates that the active component is compatible with biological control efforts and may be useful as an alternative management tool for insect pests of stored grain.

5. Insect Cuticular Proteins Isolated and Characterized. The insect exoskeleton or cuticle serves many functions including protection, locomotion, respiration, and communication. Therefore, it must have very diverse mechanical and chemical properties to provide for optimization of each function. When an insect molts from the larval to the pupal stage, the new hard, tanned cuticle is very different in physical properties from the soft larval cuticle it replaces. This change must be due in part at least to differences in the proteins that make up the cuticular layers. We described changes in the pattern of proteins from the pupal cuticle that take place during the time that new cuticular proteins are synthesized and incorporated into the cuticle structural complex. A large set of pupal cuticular proteins was detected, and a few of the most abundant proteins were selected for further characterization. These data are a starting point for a

more detailed molecular characterization of newly discovered cuticular proteins/genes and for understanding how these proteins become cross-linked during the hardening process. The results of this study provided new knowledge about insect support structures and their mechanisms of stabilization and regulation, and also yielded new insights into how insects have evolved extracellular components with different properties, which contributed to their great diversity and success in nature. The information will be useful to scientists involved in the development of biotechnological methods of insect pest control, which are designed to disrupt insect cuticle physiology. Inhibition of this structural protein chemistry would disrupt cuticle formation and prevent insect growth and development.

6. Insect Digestive Enzymes Selectively Inhibited by Plant Protein. The southern corn rootworm causes extensive damage to many grass crops. Cultivars resistant to rootworms can be developed using biotechnology. We identified and characterized a protein from potato that selectively inhibits the major proteolytic enzyme in rootworm gut extracts and also demonstrated that this protein retards insect growth when administered orally. The results indicate that the gene for this inhibitor could be manipulated through genetic engineering to develop insect-resistant plants.

7. Physical Properties of Biopesticide Improved by Genetic Engineering. One of the strategies to increase plant tolerance to insect pests is to increase the production of proteins with insecticidal activity in transgenic plants. In prior research, we showed that an insect molting enzyme called chitinase acts as a biopesticide in transgenic plants by disrupting structural components of the insect gut. However, when plants tissues were analyzed, we unexpectedly found several modified forms of the chitinase instead of a single protein. Together with scientists at Kansas State University and Kinki University in Japan, we conducted gene deletion and structure-function experiments to help identify and characterize several of the multiple forms of the biopesticidal chitinase. The data revealed how a full-length protein is processed at one end to generate smaller forms that were still toxic to pest insects. Some of these forms were more stable than the native protein. The results obtained provide useful information about biopesticide gene expression in plants and about the structures that are needed for pesticidal activity. The findings will facilitate a more effective application of the insect chitinase gene for the control of insect pests. The long-term goal of this research is to improve the properties of this biopesticide, including enzymatic activity, stability, and insecticidal activity.

8. Transgenes Inserted into Beetles. In 2000, we succeeded for the first time in producing genetically transformed beetles, using gene transfer aids constructed in 1999. Foreign genes were inserted into the chromosome of the red flour beetle using gene transfer aids derived from moths and flies. This new system can be used to insert DNA tags into target insect control genes, making it possible to identify, isolate and characterize such genes and to facilitate the incorporation of these genes into transgenic plants for insect control. The system could also be used to correct genetic defects and genetically engineer improvements in beneficial insect species. To demonstrate this possibility, we used the new system to introduce a pigmentation gene into unpigmented red flour beetles and showed that normal pigmentation was restored.

9. Chitin Synthase Gene Mapped in Flour Beetle. The chitin synthase gene is responsible for the production of chitin, the main component of insect exoskeleton. It has been located on chromosome 5 of the red flour beetle. This accomplishment makes possible a mutational analysis of this important developmental gene, which will in turn allow us to identify the regions of the gene most critical for activity and most sensitive to inhibitors.

Goals for 2001 and 2002:

Specific tasks in 2001 will be to:

1. Continue studies on the expression of the intact and truncated forms of proteins from the Indianmeal moth immune system.

2. Study chemical changes in the host insect following injection of the paralytic toxin by the parasitoid wasp, *Habrobracon hebetor*.

3. Develop physiological and/or biochemical methods for determination of age of long-lived stored-product beetles.

4. Continue studies on the chemical reactions that take place during the formation of insect cuticle and in the immune responses of insects to attacks by microorganisms.

5. Continue the development and improvement of biopesticides that can be incorporated into transgenic plants.

6. Evaluate potential insect control proteins (ICPs) that inhibit digestive and molting processes in insect pests and determine the effectiveness of these inhibitors on the growth and development of stored-product insects.

7. Continue to identify cuticle protein changes and determine how tanning enzymes cross-link these proteins and harden the exoskeleton of insects.

8. Continue to characterize genes that code for digestive enzymes and also evaluate potential insect control proteins that inhibit digestive and cuticle formation reactions.

9. Continue to test new gene tagging and gene transfer aids and characterize genes required for molting.

10. Complete new, higher resolution molecular maps and gene expression libraries of the red flour beetle genome and develop strategies that will begin to catalogue new genes that represent likely targets for pest control intervention.

Specific tasks in 2002 will be to:

1. Study the biochemical connection between how an insect immune system recognizes foreign invaders and the development of the immune response in the Indianmeal moth.

2. Characterize the immuno proteins from the Indianmeal moth that bind to bacterial cell wall components.

3. Continue our studies of the cloning of maternally-acting lethal genes in flour beetles.

4. Finish construction of the molecular map of the red flour beetle genome.

5. Continue to develop gene aids for tagging and cloning of important insect genes.

6. Use genetic studies to identify gene pathways that regulate critical insect development and survival systems.

7. Continue developing tools for insect genome analysis and gene mining.

Summary of 2000 Publications/Patents:

01. Baker, J.E., Dowell, F.E. and Throne, J.E. Detection of parasitized rice weevils in wheat kernels with near-infrared spectroscopy. Biological Control. 1999. v.16. p.88-90.

02. Baker, J.E. and Fabrick, J.A. Host hemolymph proteins and protein digestion in larval *Habrobracon hebetor* (Hymenotpera: Braconidae). Insect Biochemistry and Molecular Biology. 2000. v. 30 p. 937-946.

03. Beeman, R. W. and Lorenzen, M. The vermilion, cinnabar and polyubiquitin genes of Tribolium castaneum. Third International Workshop on Invertebrate Transgenesis Abstracts. 1999.

04. Brown, S.J., Decamillis, M., Gonzalez-Charneco, K., Denell, R., Beeman, R.W., Nie, W. and Denell, R.E. Implications of the *Tribolium* deformed mutant phenotype for the evolution of Hox gene function. Proceedings of National Academy of Science USA. 2000. v.97. p. 4510-4514.

05. Hopkins, T.L., Krchma, J., Ahmad, S. and Kramer, K.J. Pupal cuticle proteins of *Manduca sexta*: characterization and profiles during sclerotization. Insect Biochemistry and Molecular Biology. 2000. v.30. p.19-27.

06. Huang, X., Zhang, G.H., Zen, K.C., Muthukrishnan, S. and Kramer, K.J. Homology modeling of the insect chitinase catalytic domain-oligosaccharide complex and the role of a putative active site tryptophan in catalysis. Insect Biochemistry and Molecular Biology. 2000. v.30. p.107-117.

07. Kramer, K.J., Morgan, T.D., Throne, J.E., Bailey and M., Howard, J.A. Transgenic maize expressing avidin is resistant to storage pests. Nature Biotechnology. 2000. v.18. p.670-674.

08. Kramer, K.J. What do you get when a chicken gene is put into maize? If the gene is for the egg white protein, avidin, you get an insect-resistant transgenic grain. ISB News Report. 2000. August, p. 2-4.

09. Oppert, B., Hammel, R., Throne, J.E. and Kramer, K.J. Fitness costs of resistance to *Bacillus thuringiensis* in the Indianmeal moth, *Plodia interpunctella*. Entomologia Experimentalis et Applicata. 2000. v. 96. p. 281-287.

10. Perez-Mendoza, J., Fabrick, J.A., Zhu, K.Y. and Baker, J.E. Alterations in esterases are associated with malathion resistance in *Habrobracon hebetor* (Hymenoptera: Braconidae). Journal of Economic Entomology. 2000. v. 93(1). p.31-37.

11. Shippy, T.D., Guo, J., Brown, S.J., Beeman, R.W. and Denell, R.E. Analysis of maxillopedia expression pattern and larval cuticular phenotype in wild-type and mutant *Tribolium*. Genetics. 2000. v.155. p.721-731.

12. Throne, J.E., Baker, J.E., Messina, F.J., Kramer, K.J. and Howard, J.A. Varietal resistance. In: Bh. Subramanyam and D.W. Hagstrum, Editors, <u>Alternatives to Pesticides in Stored-Product IPM</u>. Kluwer Academic Publishers, Norwell, MA., 2000. p. 165-192.

13. Zhu, Y.C. and Baker, J.E. Characterization of midgut trypsin-like enzymes and three trypsinogen cDNAs from the lesser grain borer, *Rhyzopertha dominica* (Coleoptera: Bostrichidae). Insect Biochemistry and Molecular Biology. 1999. v.29. p.1053-1063.

14. Zhu, Y.C. and Baker, J.E. Molecular cloning and characterization of a midgut chymotrypsin-like enzyme from the lesser grain borer, *Rhyzopertha dominica*. Archives of Insect Biochemistry and Physiology. 2000. v.43. p.173-184.

15. Zhu, Y. C., Kramer, K.J., Dowdy, A.K. and Baker, J.E. Trypsinogen-like cDNAs and quantitative analysis of mRNA levels from the Indianmeal, *Plodia interpunctella*. Insect Biochemistry and Molecular Biology. 2000. v. 30. p. 1027-1035.

16. Zhu, Y., Oppert, B., Kramer, K.J., McGaughey, W.H. and Dowdy, A.K. cDNAs sequence, mRNA expression and genomic DNA of trypsinogen from the Indianmeal moth, *Plodia interpunctella*. Insect Biochemistry and Molecular Biology. 2000. v.9(1). p.19-26.

17. Zhu, Y.C., Oppert, B., Kramer, K.J., McGaughey, W.H. and Dowdy, A.K. cDNAs of aminopeptidase-like protein genes from *Plodia interpunctella* strains with different susceptibilities to *Bacillus thuringiensis* toxin. Insect Biochemistry and Molecular Biology. 2000. v.30. p.215-224.

For More Information on this Project Contact:

Dr. Karl Kramer
Telephone - 1-800-627-0388 or (785) 776-2711
FAX - (785) 776-2792
email - kramer@gmprc.ksu.edu

CRIS 5430-43000-019-00D - Specific Cooperative Agreement

Pest Control by Manipulation of Insect Eicosanoid Mediated Immune Responses to Bacterial Infections

Investigators: R. Howard and D. Stanley[1]

Start Date: 06/01/95   **Term Date:** 05/31/00

Problem: Conventional chemicals for control of insect pests in stored grain and commodities are at risk due to recently proposed restrictions on the use of fumigants and passage of the Food Quality Protection Act. Therefore, there is a vital need to develop alternative economically viable biochemical, genetic and integrated control methods that are compatible with environmental conservation and food safety concerns of consumers.

Objectives: We have been investigating insect immune systems as potential targets for novel strategies of insect pest management. In particular, we have focused on the biochemical signals that operate between the start of bacterial infections and the cellular reactions to the infections. We have demonstrated that certain metabolites of polyunsaturated fatty acids, known as prostaglandins and related eicosanoids, initiate insect immune reactions to infections. We have also shown that inhibition of eicosanoid biosynthesis in the early phases of an infection severely limits the ability of insects to overcome infections. The goal of this project is to further investigate inhibition of insect immune response to disease as a control method.

Results and Impact: Working with Dr. David Stanley at the University of Nebraska, we continued our studies on the chemical components of bacterial cell walls that elicit eicosanoid-mediated insect immune reactions. Specifically, additional bacterial lipopolysaccharides were purified and shown to trigger insect immune responses. New studies were initiated with the fungal pathogen, *Beauveria bassianna*, to assess its ability to elicit insect immune responses, and to establish whether eicosanoids were involved in any immune reactions. The fungus did produce immune responses in *Manduca sexta* (tobacco hornworm) larvae and preliminary data suggest that eicosanoids are involved. The impact of this work lies in the development of a more detailed understanding of the roles of eicosanoids in insect immunity. This may lead to the discovery of novel agents that can specifically interrupt the life cycles of pest insects by inhibiting the biosynthesis of eicosanoids, which are crucial mediators of immunity to bacterial infections in insects.

Goals for 2001 and 2002: Project ended 6/30/2000.

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[1]Department of Entomology, University of Nebraska, Lincoln, NE

2000 Publications:

01. Bedeck, J.C., Pardy, R.L., Howard, R.W. and Stanley, D.W. Insect cellular reactions to the lipopolysaccharide component of the bacterium, *Serratia marcescens*, are mediated by eicosanoids. Journal of Insect Physiology. 2000. v.46(11). p.1481-1487.

For More Information on this Project Contact:

Dr. Ralph Howard
Telephone - 1-800-627-0388 or (785) 776-2706
FAX - (785) 776-2792
email - howard@gmprc.ksu.edu

CRIS 5430-43000-019-00D - Specific Cooperative Agreement

Development of Insect Chitinolytic Enzymes as Biopesticides

Investigators: K. Kramer and S. Muthukrishnan[1]

Start Date: 10/01/96   **Term Date:** 03/26/02

Problem: New practical and effective means for controlling insect pests are needed to replace the traditional chemical control methods.

Objectives: Chitin is a major structural component of insects. The goal of this project is to characterize the physiological and genetic processes underlying chitin metabolism in insects, which can be manipulated in order to develop control tactics using biopesticides and insect growth regulators.

Results and Impact: During 2000, we incorporated several forms of chitinolytic enzyme genes from insects into corn and wheat. Dr. S. Muthukrishnan from Kansas State University, Manhattan, KS was the cooperator. Bioassays demonstrated that when insects ate plants containing the chitinase enzymes synthesized as a result of these genes, their normal digestive functions were inhibited because this enzyme attacked certain structural components in the insect gut. We also manipulated this gene in plants so that a variety of different forms of this enzyme have been produced. This has provided a great deal of information about which parts of the enzyme's structure are needed for optimal activity and which forms are useful for insect resistance.

Goals for 2001 and 2002:

Specific tasks in 2001 and 2002 include:

1. Continue characterizing genes for molting enzymes and also evaluate other potential insect control proteins that inhibit the molting process.

2. continue evaluating transgenic corn and wheat plants expressing chitinolytic enzymes for host plant resistance to insect pests.

3. Continue characterizing the properties of recombinant chitinolytic enzymes including insecticidal potential.

2000 Publications: None at this time.

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[1]Department of Biochemistry, Kansas State University

For More Information on this Project Contact:

Dr. Karl Kramer
Telephone - 1-800-627-0388 or (785) 776-2711
FAX - (785) 776-2792
email - kramer@gmprc.ksu.edu

CRIS 5430-43000-019-00D - Specific Cooperative Agreement

Genetic and Molecular Analysis of Limb Development in the Beetle *Tribolium castaneum*

Investigators: R. Beeman, S. J. Brown[1], and D. Tautz[2]

Start Date: 08/01/99   **Term Date:** 07/31/02

Problem: Stored-product insects cause numerous problems throughout grain production and marketing channels, which relate to the storage, marketing, and utilization of wheat, sorghum, corn, rice, barley, oats, soybeans, and triticale. These pests are detrimental to commodity nutritional value, consumer acceptance, and end-use performance. As value is added to these commodities, losses become even more significant. Because export markets depend on high quality products, any reduction in grain quality will result in loss of economic benefits to the American farmer and processor. Novel pest management practices are needed to prevent spoilage or contamination by post-harvest pests and pathogens and to maintain overall commodity quality during handling, conditioning, storage, and processing.

Objectives: The main objective for this project is to develop novel control techniques that offer an alternative to environmentally hazardous chemical insecticides, and that can significantly reduce these commodity losses. Specifically, we are characterizing genes and developmental pathways in stored product insects that can be manipulated and we are developing control tactics using biopesticides and transgenic plants that can attack weaknesses in these pathways.

Results and Impact: During 2000, we initiated the process of mapping the whole genome of the red flour beetle. We established a scaffold map encompassing 9 of the 10 chromosomes, and began to fill in the details. This work will create the first high-resolution genetic map of a pest beetle, and will facilitate gene mining and genome analysis in many other beetles, which comprise the largest group of pest species among all insects.

Goals for 2001 and 2002:

Specific tasks in 2001 will be to work on the completion of the genetic mapping of the red flour beetle.

Specific tasks in 2002 will be to continue with the incorporation of all known genes and DNA markers for this insect into this map.

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[1]Department of Biology, Kansas State University

[2]Institute of Genetics, University of Koelz, Koeln, Germany

2000 Publications: None at this time.

For More Information on this Project Contact:

Dr. Richard Beeman
Telephone - 1-800-627-0388 or (785) 776-2710
FAX - (785) 776-2792
email - beeman@gmprc.ksu.edu

CRIS 5430-43000-019-00D - Cooperative Research and Development Agreement

Pest Control Implications of Several *Tribolium castaneum* Genes

Investigators: R. Beeman and L. Zydowsky[1]

Start Date: 07/01/98   **Term Date:** 06/30/01

Cooperator: Exelixis Pharmaceuticals, San Francisco, California

Problem: The most studied model for insect behavior has been the fruit fly. This is not the best genetic model for the study of insect pest behavior. Therefore, a better model for pest insect genetic studies is needed. In addition, previous research has shown that lethal genes are wide spread in pest insect populations. An example of such a gene is the Medea maternal lethal gene. Female insects with this gene pass it on to some of their progeny. Those progeny that do not inherit it, die while those that do inherit it live. Research is needed to identify such genes and determine their mechanisms of action.

Objectives: This project is designed to establish the red flour beetle (*Tribolium*) as a model for genetic studies for pest insects. Another major goal is the identification of other lethal genes such as the Medea and a development of an understanding of how these genes work. This may lead to additional control mechanisms for these insect pests.

Results and Impact: During 2000, we cloned and sequenced a segment of DNA in the red flour beetle that includes the maternal larvicidal "Medea" gene as well as many other interesting genes. The gene appears to produce a toxin-antitoxin combination in this insect, and young insects die unless they produce the antitoxin. Insect genes and gene pathways identified and cloned using these tools will ultimately be expressed in plants to disrupt the physiology of plant-feeding insects.

Goals for 2001 and 2002:

Specific tasks in 2001 will be to identify the DNA and protein produced by the "medea" gene. We also will continue to develop the red flour beetle as an important genetic model for studying insect pests that are important to agriculture.

Specific tasks in 2002 will be to develop strategies to exploit the "medea" gene for the development of new insect control techniques. We also plan to characterize the genetic pathways that regulate the processes vital to insect development and survival.

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[1]Exelixis Pharmaceuticals, Inc., South San Francisco, CA

2000 Publications:

01. Beeman, R.W. and Brown, S.J. RAPD-based genetic linkage maps of *Tribolium castaneum*. Genetics. 1999. v.153. p.333-338.

For More Information on this Project Contact:

Dr. Richard Beeman
Telephone - 1-800-627-0388 or (785) 776-2710
FAX - (785) 776-2792
email - beeman@gmprc.ksu.edu

CRIS 5430-43000-020-00D

Biological Control of Stored-Product Insects

Project Leader: R. Howard   **Investigators:** R. Howard, B. Oppert, and J. Lord

Full-Time Scientist Equivalents (SYs): 3.0   **Net Funding to Location per Year:** $ 619,047

Start Date: 10/27/99   **Term Date:** 10/26/04

Problem: Economic losses of post-harvest food and fiber due to damage caused by storage insect pests cost U.S. consumers and producers billions of dollars every year. Traditional chemical control methods for insect pests that attack stored grain and commodities are rapidly being lost because insects are developing resistance to insecticides, general public awareness of environmental and food safety concerns is increasing, and more stringent regulatory restrictions are being placed on the use of insecticides. The development of economically sound, environmentally-safe biocontrol agents for storage insect pests is urgently needed. Biological control agents have more complex interactions with pest species than conventional pesticides and fumigants. Successful implementation of biological control will require a better understanding of the biology of the pests as well as their natural enemies. The practical development of such agents is hindered by inadequate knowledge of the biology and biochemistry of the agents. We need to understand how pests respond and adapt to biocontrol agents.

Objectives: The long term goals of this project are to develop economically viable biological, genetic, and integrated control methods for stored product pests that are compatible with the environment and with conservation of natural resources. Three major objectives this past year were to:

1. Determine How to Effectively Manipulate the Behavior of Pests and Parasitoid Wasps to Control Stored Product Insect Pests. This research involves behavioral and chemical studies on storage pests and several species of wasps which attack stored product insect pests. The goal of this research is to understand how the storage pests distribute themselves in various commodities and maximize their reproductive potential, and how wasps find, recognize, and attack their hosts and how this information can be used to develop better control methods. It also involves combining the wasps with fungal pathogens and assessing the combined effects of these two biological control agents.

2. Determine How Stored Product Insects Resist Infections of the Bacterial Pathogen, *Bacillus thuringiensis* (Bt), and Its Toxins and Develop Ways to Overcome This Resistance. This research involves studying enzymes known as digestive proteinases from the Indianmeal moth, a major pest of stored products, and relating levels of activity of these enzymes to tolerance of the moths to bacterial infections. Proteinases can affect the toxicity of ingested insecticidal pathogens. Our research will identify methods to enhance the efficacy of Bt-based products in insect pests.

3. Determine How Entomopathogens (Bacteria, Fungi, Protozoa, etc.) Invade and Kill Stored Product Insects and Develop Integrated Pest Management Approaches Based on This Information. Entomopathogens include a large number of fungi, bacteria, protozoa, etc., that can attack and kill stored-grain insect pests. This research involves the study of several different kinds of entomopathogens and their effects on different stored-product pests under different environmental conditions.

Results and Impact:

1. Determine How to Effectively Manipulate the Behavior of Pests and Parasitoid Wasps to Control Stored Product Insect Pests. Better biological control technologies using parasitic wasps are needed for stored product insect pests. An important problem is to understand how these wasps find and recognize each other and produce offspring. Surface chemicals, known as cuticular hydrocarbons, on a major grain pest parasitoid were shown to function as species and gender recognition cues and were shown not to vary, even when the parasitoid was reared on different hosts. Such information will be useful in designing studies to manipulate the wasp's behavior to maximize the amount of time they spend in the stored product commodity mating and searching for stored product pests to kill.

The red flour beetle, *Tribolium castaneum*, is a major pest of flour mills and other food processing and storage facilities. The location of patches of food strongly influences the abundance and distribution of individuals in a landscape and this in turn dictates where pest management needs to be targeted. We investigated how food patch size influences egg laying behavior and the fitness consequences of different egg laying decisions. Females adjusted the number of eggs that they laid in a given patch as a function of amount of flour present. Females visited multiple patches and the allocation of eggs among patches was influenced by the amount of flour in the patch. There was a good correlation between the number of eggs laid and the optimal number of eggs to maximize offspring survival to adulthood. Understanding patch use behavior will help improve the management of pest populations in food processing and storage facilities.

Certain species of nematodes are lethal parasites of many species of insects. These nematodes are small (less then 1/16 inch) round worms that have the ability to seek out insects and kill them. They are also commercially available and initial results indicate that they may be effective against insects that infest grain and grain products. Initial data indicate that one of the nematodes (*Steinernema carpocapsae*) is very effective at attacking the larvae of Indianmeal moths and moderately effective at attacking red flour beetle adults. Further research is being conducted to determine how effective the nematodes will be at finding and killing insects in the structure of buildings and the influence of low relative humidity on their effectiveness.

The rice weevil, *Sitophilus oryzae*, is a seed parasite that is a major pest of stored grain. Seed selection behavior has important fitness consequences for the weevil and, as a result, has an

impact on pest behavior, spatial distribution, population dynamics, and level of damage. To maximize the number of progeny that they produce, seed parasites need to make decisions about the number of eggs to lay in a host. Results of this study indicate that seed size influenced the number of eggs laid and their location. The primary mechanism for laying more eggs in larger kernels was that the acceptance time was shorter for small kernels and that some evaluation of size was occurring prior to the weevil walking on the seed. Weevils frequently laid more eggs in the kernels than could complete development and this supports the idea that they are not able to discriminate infected from uninfected kernels. Females previously exposed only to small sized kernels were more likely to lay eggs in small kernels than females previously exposed only to large kernels. This indicates that a component of size discrimination is learned.

2. Determine How Stored Product Insects Resist Infections of the Bacterial Pathogen, *Bacillus thuringiensis* (Bt), and Its Toxins and Develop Ways to Overcome This Resistance. Our pioneering research has provided valuable insights in understanding insect resistance to Bt. Using our Bt-susceptible and -resistant Indianmeal moths as a model system, research has demonstrated that insects adapt to Bt toxins by a loss in gut toxin receptors or toxin-activating proteinases. Digestive proteinases from Bt-susceptible and -resistant Indianmeal moths were cloned and sequenced. Fitness cost measurements provided evidence that some Bt-resistant Indianmeal moths have costs associated with resistance while others do not.

Other research included a description of digestive proteinases in a major pest of alfalfa, the alfalfa weevil. This research is a prelude to the design of transgenic alfalfa to provide host-plant resistance to the weevil. This information will also supplement our knowledge of weevil digestive physiology in the study of stored product weevils. An invited book chapter was completed and provides a comprehensive review of plants transformed with digestive proteinase inhibitors.

3. Determine How Entomopathogens (Bacteria, Fungi, Protozoa, etc.) Invade and Kill Stored Product Insects and Develop Integrated Pest Management Approaches Based on This Information. Chemical hormones known as eicosanoids have been shown to be important regulators of pest insect immune responses to bacterial attack and temperature and ion and water regulation. Under a variety of stresses, eicosanoid functions are greatly diminished. Studies were undertaken to utilize eicosanoid inhibitors to weaken the immune responses of stored product pests, and hence make them more susceptible to biological control agents, including entomopathogens. Eicosanoids were implicated in insect immune responses to fungi. Evidence for the involvement of a specific eicosanoid biosynthetic pathway in triggering the response to fungi was obtained. These studies are in a preliminary stage and work is continuing.

Commercial and potentially commercial strains of the insect-infecting fungus, *Beauveria bassiana*, were tested for their effects on various stored-product beetles. There was wide variation in the susceptibility among the target species and between adults and larvae. The survival of fungus spores on the principal stored-product substrates was greater than 30 days. High humidity was not required to achieve infection of pest insects with fungi. These results will

help to demonstrate the practicality of using these fungi for controlling the insect pests that infest stored grain and other products.

Protozoa are single-celled organisms like the amoeba. Micrographs of the external structure of a protozoan pathogen found on stored-product insects provided evidence that the pathogen may represent a new discovery. Host range studies revealed that both moth and beetle pests can be infected by the organism.

4. Responding to customer requests, a web site was developed for downloading stored product insect images (http://bru.usgmrl.ksu.edu/images). The database contains over 130 images of 30 different stored product pests in easy-to-download jpeg files. This information will provide a valuable resource for researchers, educators, and the general public.

Goals for 2001 and 2002:

Specific tasks in 2001 will be to:

1. Continue to develop a better understanding of the behavioral and chemical mechanisms used by storage pests and by their natural enemies and how natural enemies locate pest insect species and find mates. We will also examine chemical and behavioral interactions among different natural enemies that attack stored product insects.

2. Incorporate new molecular techniques in the study of digestive proteinases of stored product pests.

3. Continue to evaluate new compounds and pathogens, especially insect specific protozoans, for the development of pest insect control methods, and develop improved production systems for insect pathogens.

4. Characterize insect pathogenic fungus attachment and infection processes with the intent of identifying synergistic agents.

Specific tasks in 2002 will be to:

1. Use information gained in 2001 to refine the investigations of the behavioral and semiochemical mechanisms used by storage pests and by their natural enemies.

2. Use information gained in 2001 to identify processes that are involved in the regulation of stored product insect digestion.

3. Achieve a better understanding of the mechanisms of attachment and germination of insect pathogenic fungi.

Summary of 2000 Publications/Patents:

01. Campbell, J.F. Experimental design: statistical considerations and analysis. Lacey, L.A. and Kaya, H. K., Editors. Kluwer Academic Publishers, Dordrecht, The Netherlands. <u>Field Manual of Techniques in Invertebrate Pathology</u>. Chapter II. 2000. p.39-76.

02. Campbell, J.F. and Kaya, H.K. Influence of insect associated cues on the jumping behavior of entomopathogenic nematodes (*Steinernema spp.*). Behaviour. 2000. v.137(5). p.591-609.

03. Campbell, J.F. and Kaya, H.K. Mechanism, kinematic performance, and fitness consequences of entomopathogenic nematode (*Steinernema spp.*) jumping behavior. Canadian Journal of Zoology. 1999. v.77(12). p.1947-1955.

04. Howard, R.W. and Stanley, D.W. The tie that binds: Eicosanoids in invertebrate biology. Annals Entomological Society of America. 1999. v.92(6). p.880-890.

05. Huang, F., Zhu, K.Y., Buschman, L.L., Higgins, R.A. and Oppert, B. Comparison of midgut proteinases in Bacillus thuringiensis-susceptible and resistant European corn borer, *Ostrina nubilalis*. Pesticide Biochemistry and Physiology. 1999. v.65(2). p.132-139.

06. Moore, D., Lord, J. C. and Smith, S. Pathogens. In <u>Alternatives to Pesticides in Stored-Product IPM</u>, Bh. Subramanyan and D. W. Hagstrum, Editors. Kluwer Academic Publishers, Dortrecht, The Netherlands. 2000. p. 193-227.

07. Oppert, B. Protease interactions with *Bacillus thuringiensis* insecticidal toxins. Archives of Insect Biochemistry and Physiology. 1999. v.42(1). p. 1-12.

08. Oppert, B., Hammel, R., Throne, J. E. and Kramer, K. J. Fitness costs of resistance to *Bacillus thuringiensis* in the Indianmeal moth, *Plodia interpunctella* (Lepidoptera: Pyralidae). Entomologia Experimentalis et Applicata. 2000. v. 96. p. 281-287.

09. Oppert, B., Hartzer, K. and Smith, C. M. Characterization of the digestive proteinases of *Hypera postica* (Gyllenhal) (Coleoptera: Curculionidae). Transactions of Kansas Academy of Science. 2000. v. 103 p. 99-110.

10. Oppert, B. Transgenic plants expressing enzyme inhibitors and the prospects for biopesticide development. In <u>Phytochemical Biopesticides</u>, O. Koul, and G. S Dhaliwal, Editors, 2000. Harwood Academic, The Netherlands. p. 83-95.

11. Reeck, G., Oppert, B., Denton, M., Kanost, M., Baker, J. and Kramer, K. Insect proteinases. Turk, V., editor. Birkhauser, Basil, Switzerland. Proteases, New Perspectives. 1999. p.125-148.

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For More Information on this Project Contact:

Dr. Ralph Howard
Telephone - 1-800-627-0388 or (785) 776-2706
FAX - (785) 776-2792
email - howard@gmprc.ksu.edu

CRIS 5430-43000-021-00D

Decision-Making Tools for Integrated Pest Management of Stored-Product Insects

Project Leader: D. Hagstrum   **Investigators:** D. Hagstrum, P. Flinn, and J. Throne

Full-Time Scientist Equivalents (SYs): 3.0   **Net Funding to Location per Year:** $ 823,970

Start Date: 10/27/99   **Term Date:** 10/26/04

Problem: Insects cause major reductions in the quality of stored grain and other stored products in the U.S. and around the world. This is a very serious problem because each year it is estimated that losses due to insects in stored grain are 5% to10% in developed countries and up to 30% in developing countries. In the U.S., this amounts to losses ranging from 1.2 to 2.4 billion dollars per year. New regulations are increasing the cost and difficulty of using pesticides, and insects are becoming resistant to pesticides. More cost-effective pest management programs are urgently needed to maintain the quality of the food supply in the U.S. and our competitiveness in global markets.

Objectives: The major objective for this project focuses on the development of improved integrated pest management (IPM) of stored-product insects through better monitoring methods and through the use of models to predict insect population levels. This should reduce the use of pesticides in stored products. Current knowledge of pest biology, movement, and population ecology is inadequate to develop and implement biologically-sound and environmentally-compatible pest control technologies and cost-effective insect monitoring programs. A systems approach is needed to help optimally manage insect problems in stored products.

Research on this project provides the technology that storage managers need to detect insect infestations more accurately and earlier, predict insect population growth rates and effects of different control measures, and forecast when insect control will be needed. These management tools are needed for a transition to integrated pest management programs with decreased use of chemical pesticides and fumigants. We are conducting experiments on the effects of temperature and moisture on insect population dynamics. We are using this information to build and validate accurate models that predict how long grain and other stored products can be stored before the number of insects reaches damaging levels. The models also predict the effects of different management actions such as aeration and fumigation on insect infestations. The models are used in an existing expert system (Stored Grain Advisor) to aid farmers and grain handlers in making better pest management decisions and in reducing fumigation failures. A version of this expert system (SGA-Pro) is being developed for elevator managers.

Results and Impact:

1. Development of SGA-Pro Was Continued. The spatial model for farm-stored grain was modified for elevator storage. Major changes to the model were: the allowable bin height was increased to 120 feet, bin wall material was changed to concrete, and insect immigration rates and distributions within the bin were adjusted to fit actual field data. In general, the model predicted lesser grain borer population density and distribution within the bin accurately. This model will be used in a decision support system we are developing for elevators, as part of the area-wide IPM program for insect pests in stored wheat. This model will improve pest management decisions by elevator managers by predicting safe-storage intervals and by predicting the economics of different insect control strategies.

2. Phosphine Mortality Studies Were Completed. Studies were completed on the effects of temperature and insect stage on phosphine-induced mortality for the lessor grain borer, rusty grain beetle, and rice weevil insect species. These data will be used to develop a model to predict effectiveness of fumigation.

3. Predictions of the Numbers of Parasitic Wasps Needed for Pest Control Were Developed. A functional response model was developed for the parasitic wasp *Theocolax elegans* attacking the lesser grain borer. This is a first step toward predicting the number of parasites that need to be released to control pests and the best time for releasing them. We also produced a population growth model for the Indianmeal moth, one of the major pests of stored food products and commodities in the U.S. This model will be used to assist with the development of control strategies for this pest.

4. Development of Tools for Determining Insect Population Densities Was Continued. The number of samples needed to accurately estimate insect density depends upon the relationship between mean insect density and variations in the numbers of insects per sample. Using a generic nonlinear variance-mean equation instead of developing a new linear variance-mean equation for each new sampling program can reduce the cost of developing a sampling program. Using a sequential sampling plan instead of a fixed number of samples can reduce the cost of sampling. However, methods available for developing a sequential sampling plan from a linear variance-mean equation do not work for the generic nonlinear variance-mean equation. In collaboration with Bhadriraju Subramanyam at Kansas State University and Steve Naranjo at Western Cotton Research Laboratory, Phoenix, Arizona, methods are being developed for using the generic nonlinear variance-mean regression equation for stored-product insects to do sequential sampling. In collaboration with Steve Naranjo, the generic nonlinear variance-mean equation for stored-product insects also has been shown to work for the sweetpotato whitefly. This suggests that the generic nonlinear variance-mean equation might work well for other insect species too.

Goals for 2001 and 2002:

Specific Tasks in 2001 will be to:

1. Collect additional data on the use of aeration controllers to increase the effectiveness and reduce the cost of suppressing insect populations by cooling the grain shortly after it is placed into storage.

2. Test the version of the Stored Grain Advisor Expert System called SGA Pro designed to optimize its prediction capabilities in large grain elevators.

3. Develop models that correctly predict for different insect pest densities, life stages, and grain temperatures and humidities the insect mortality in storage bins treated with phosphine.

4. Continue to evaluate breeding lines of corn for resistance to storage insect pests.

5. Develop sampling plans for determining insect infestation levels in rail cars.

Specific Tasks in 2002 will be to:

1. Complete the development of decision tools and insect monitoring programs that will help managers make better pest management decisions.

2. Continue to evaluate breeding lines of corn for resistance to storage insect pests.

3. Release the SGA Pro developed for use in commercial grain elevators.

Summary of 2000 Publications/Patents:

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02. Baker, J.E., Dowell, F.E. and Throne, J.E. Detection of parasitized rice weevils in wheat kernels with near-infrared spectroscopy. Biological Control. 1999. v.16. p.88-90.

03. Baker, J.E. and Throne, J. E. Angoumois grain moth. Steffey, K.L., Rice, M.E., All, J., Andow, D.A., Gray, M.E., Van Duyn, J.W., Editors. Handbook of Corn Insects. Entomological Society of America, Lanham, MD. 1999. p.44-45.

04. Burks, C. S., Baker, J.E. and Hagstrum, D.W. Optimal host age and stage for development of *Anisopteromalus calandrae* (Hymenoptera: Pteromalidae) reared on the rice weevil (Coleoptera: Curculionidae) in wheat. Journal of the Kansas Entomological Society. 1999. v.72. p.448-455.

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05. Burks, C.S. and Hagstrum, D.W. Rapid cold hardening capacity in five species of coleopteran pests of stored grain. Journal of Stored Product Research. 1999. v. 35. p. 65-75.

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07. Dowell, F.E., Broce, A.B., Xie, F., Throne, J.E. and Baker, J.E. Detection of parasitized fly puparia using near-infrared spectroscopy. Journal of Near Infrared Spectroscopy. 2000. v. 8. p. 259-265.

08. Flinn, P.W. and Hagstrum, D.W. Augmentative releases of parasitoid wasps in stored wheat reduces insect fragments in flour. Journal of Stored Product Research. 2000. v.37. p. 179-186.

09. Hagstrum, D.W. Using five sampling methods to measure insect distribution and abundance in bins storing wheat. Journal of Stored Product Research. 2000. v.36. p.253-262.

10. Hagstrum, D.W. and Bh. Subramanyam. Monitoring and decision tool. In Bh. Subramanyam and D. W. Hagstrum, Editors, Alternatives to Pesticides in Stored-Product IPM. Kluwer Academic Publishers. 2000. p. 1-28.

11. Hagstrum, D.W. and Bh. Subramanyam. Integration. In Bh. Subramanyam and D. W. Hagstrum, Editors, Alternatives to Pesticides in Stored-Product IPM. Kluwer Academic Publishers. 2000. p. 419-428.

12. Kramer, K.J., Morgan, T.D. Throne, J.E. Dowell, F.E., Bailey, M. and Howard, J.A. Transgenic avidin maize is resistant to storage insect pests. Nature Biotechnology. 2000. v. 18. p. 670-674.

13. Miller, R.J., Broce, A.B., Dryden, M.W. and Throne, J.E. Emergence, survival, and fecundity of adult cat fleas (Siphonaptera: Pulicidae) exposed as pupae to juvenile hormone mimics. Journal of Medical Entomology. 1999. v.36(6). p.776-779.

14. Oppert, B., Hammel, R.A.,Throne, J.E. and Kramer, K.J. Fitness costs of resistance to *Bacillus thuringiensis* in the Indianmeal moth, *Plodia interpunctella*. Entomologia Experimentalis et Applicata. 2000. v. 96 p. 281-287.

15. Perez-Mendoza, J., Hagstrum, D.W., Dover, B.A., Hopkins, T.L. and Baker, J.E. Flight response, body weight, and lipid content of *Rhyzopertha dominica* (F.) (Coleoptera: Bostrichidae) as influenced by strain, season, and phenotype. Journal of Stored Product Research. 1999. v. 35 p. 183-196.

16. Perez-Mendoza, Dover, B.A., Hagstrum, D.W. and Hopkins, T.L. Effect of crowding, food deprivation, and diet on flight initiation and lipid reserves of the lesser grain borer, *Rhyzopertha dominica* (F.) (Coleoptera: Bostrichidae). Entomologia Experimentalis et Applicata. 1999. v. 91 p. 317-326.

17. Scholler, M. and Flinn, P.W. Parasitoids and Predators. In Bh. Subramanyam and D. W. Hagstrum, Editors, Alternatives to Pesticides in Stored-Product IPM. Kluwer Academic Publishers. 2000, p.229-271.

18. Throne, J.E., Baker, J.E., Messina, F.J., Kramer, K.J. and Howard, J.A. Varietal resistance. *In* Bh. Subramanyam and D.W. Hagstrum, Editors, Alternatives to Pesticides in Stored-Product IPM. Kluwer Academic Publishers, Boston, MA. 2000. p. 165-192.

For More Information on this Project Contact:

Dr. David Hagstrum
Telephone - 1-800-627-0388 or (785) 776-2718
FAX - (785) 776-2792
email - hagstrum@gmprc.ksu.edu

Factors Influencing Flight and Dispersal of Lesser Grain Borer Adults

Investigators: D. Hagstrum, B. Dover[1], and D. Margolies[1]

Start Date: 07/15/98   **Term Date:** 07/15/00

Problem: Lesser grain borers are a serious pest of stored wheat throughout much of the world and better methods of pest management are needed. This project will identify environmental and biological factors that cause the lesser grain borer adult to disperse from stored wheat, and determine whether these factors can be used to manage these insect pests. Lesser grain borers feed inside kernels of grain, are difficult to remove prior to milling, and are a major source of insect fragments in flour. Populations are kept within tolerable limits by regular use of phosphine, but regulations are making it more difficult and costly to use phosphine and insects are becoming resistant. Cost-effective pest management programs that are less dependent upon toxic pesticides are needed to keep insect fragments in flour from exceeding levels at which flour can be sold. This project will identify environmental and biological factors that cause the lesser grain borer to disperse from stored wheat, and determine whether these factors can be used to manage this insect pest.

Objectives: The goal of this research is to obtain a better understanding of the dispersal behavior and population dynamics of the lesser grain borer, an important insect pest of stored grain. This will help us to better manage this pest species.

Results and Impact: Equipment was designed and built for determining the influence of carbon dioxide and lesser grain borer aggregation pheromone on flight initiation by lesser grain borer adults. The number of take-offs increased as carbon dioxide or pheromone concentration increased. The percentages of adults taking-off were 5, 11, 17 and 75 with atmospheres of 10, 25, 50 and 75% carbon dioxide, respectively. For 0.5, 1, 10, 50 and 100 microgram concentrations of aggregation pheromone, the take-off percentages were 0, 3, 8, 27 and 43, respectively. Clearly, both carbon dioxide or pheromone concentration are important in initiating flight and might be manipulated to manage lesser grain borer populations.

Goals for 2001 and 2000: These studies are completed.

2000 Publications: None at this time.

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[1]Department of Entomology, Kansas State University

For More Information on this Project Contact:

Dr. David Hagstrum
Telephone - 1-800-627-0388 or (785) 776-2718
FAX - (785) 776-2792
email - hagstrum@gmprc.ksu.edu

CRIS 5430-43000-014-00D - Specific Cooperative Agreement

Effects of Temperature Gradients on Movement of Insects in Stored Grain

Investigators: P. Flinn, D. Weaver[1], and K. O'Neil[1]

Start Date: 08/01/97   **Term Date:** 07/31/01

Problem: Insects cause major reductions in stored-grain quality in the U.S. and around the world. This problem impacts basic food quality and safety as well as international trade because many customers now request grain that is free from insects that also does not contain pesticide residues. Producers and grain managers need advice on the best way to manage their grain stores to minimize insect and mold damage, while also reducing the use of insecticides. When grain is not aerated in the fall, the center of the grain mass remains warmer longer. Consequently, high numbers of insects can develop in the center of the grain mass leading to losses in grain quality. By studying how insects move in temperature gradients, we can predict where insect problems are likely to occur and how to avoid them.

Objectives: The main goal of this project is to investigate how the rusty grain beetle, lesser grain borer, maize weevil, rice weevil, and red flour beetle respond to temperature gradients in grain.

Results and Impact: Cooperative studies completed by David Weaver and Kevin O'Neil at Montana State University, Bozeman, MT showed that, when given a choice of temperatures ranging from 10° to 40°C, the adult maize weevil spent most of its time at 10 to 15°C but laid the most eggs in the 18 - 26°C zone. This information will be used develop better sampling protocols for use by producers and grain handlers. Studies at GMPRC also showed that the lesser grain borer did not prefer warmer or cooler regions of grain when exposed to grain maintained at a gradient of 20 to 24°C.

Goals for 2001 and 2002:

Specific Tasks for 2001 will be to study the effects of temperature gradients on the movement of the red flour beetle. We will develop a mathematical model that predicts the movement of these beetles in a temperature gradient, and incorporate this model into the Stored Grain Advisor Pro decision support system. This project terminates in 2001.

2000 Publications: None at this time.

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[1]Department of Entomology, Montana State University

For More Information on this Project Contact:

Dr. Paul Flinn
Telephone - 1-800-627-0388 or (785) 776-2707
FAX - (785) 776-2792
email - flinn@gmprc.ksu.edu

CRIS 5430-43000-021-00D - Specific Cooperative Agreement

Decision Support System for Insect Pests in Grain Elevators

Investigators: P. Flinn, J. Throne, D. Hagstrum, and D. Soldan[1]

Start Date: 05/01/99   **Term Date:** 04/30/04

Problem: Wheat production in the U.S. is a multi-billion dollar industry. Stored grain insects and molds cause millions of dollars in losses each year. This problem impacts basic food quality and safety of wheat stores. It also impacts international trade because many buyers now request grain that is insect free and without pesticide residues. Farmers and grain managers need advice on the best way to manage their grain stores to minimize insect and mold damage, while also reducing the use of insecticides. They need accurate predictions of insect populations and the effects of control methods such as fumigation and aeration on insect population growth.

Objectives: The object of this project is further development of the Stored Grain Advisor (SGA) expert system. New model components will be developed and put into the SGA to aid elevator managers and farmers in making better decisions and reducing fumigation failures. The expert system uses the models to predict insect density and to suggest effective integrated pest management strategies for stored-grain. It emphasizes the use of preventative nonchemical controls such as cooling the grain as soon as possible using automatic aeration controllers.

Results and Impact: Work on the development of a new version of SGA Pro for specific use in grain elevators continued and a prototype was developed for testing. A risk analysis database was added to the system. Based on insect sampling data, the system tells the grain manager which bins need to be fumigated. The benefit of this system is that it reduces fumigant usage by targeting only those bins that need to be fumigated. This also saves the manager money because the entire facility does not need to be fumigated.

Goals for 2001 and 2002: In 2001 and 2002, a prototype of SGA Pro will be field tested using elevator data from the area-wide IPM project for grain storage in Kansas and Oklahoma.

2000 Publications: None at this time.

For More Information on this Project Contact:

Dr. Paul Flinn
Telephone - 1-800-627-0388 or (785) 776-2707
FAX - (785) 776-2792
email - flinn@gmprc.ksu.edu

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[1]Department of Electrical and Computer Engineering, Kansas State University

CRIS 5430-43000-021-00D - Specific Cooperative Agreement

Effects of Temperature and Life Stage on Phosphine Mortality for 3 Species of Stored-Grain Insects

Investigators: P. Flinn, J. Throne, D. Hagstrum, F. Arthur, and T. Phillips[1]

Start Date: 08/01/97   **Term Date:** 07/31/01

Problem: Insects cause major reductions in stored-grain quality in the U.S. and around the world. Phosphine is the primary fumigant used to kill insects in commercial and farm storage in the U.S. Failures in phosphine fumigation often result if the grain is cool or the bin is not well sealed.

Objectives: The objective of this project is to determine the effects of temperature and life stage on phosphine-induced mortality for three species of stored-grain insects, the lesser grain borer, rice weevil, and rusty grain beetle. Results from these experiments will be used to develop mathematical models that predict the effects of phosphine fumigation on stored-grain insect population dynamics. The models will be incorporated into an existing expert system (Stored Grain Advisor) to aid elevator managers and farmers in making better decisions and reducing fumigation failures.

Results and Impact: Studies on the phosphine mortality for the rice weevil were conducted cooperatively by Dr. Tom Phillips at Oklahoma State University. Six temperatures and five life-stages of insects were examined. Results showed that the egg and pupal stages were the most resistant, and that lower temperatures required longer fumigation times. A model was developed that can predict mortality over a range of temperatures for each life stage. This model will be used in the Stored Grain Advisor program to predict the effectiveness of phosphine fumigations. This software is currently being used to train grain managers in Montana and Oklahoma.

Goals for 2001 and 2002: Studies on the phosphine mortality of the rusty grain beetle will be completed over a range of temperatures. Data obtained will be used to refine the prediction capabilities of the Stored Grain Advisor. This project terminates 2001.

2000 Publications: None at this time.

For More Information on this Project Contact:

Dr. Paul Flinn
Telephone - 1-800-627-0388 or (785) 776-2707
FAX - (785) 776-2792
email - flinn@gmprc.ksu.edu

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[1]Department of Entomology, Oklahoma State University

CRIS 0500-00044-004-00D

Development of a Stored Wheat Area-Wide Management Program in Kansas and Oklahoma

Project Leader: D. Hagstrum   **Investigators:** D. Hagstrum, P. Flinn, J. Throne, F. Arthur, M. Mullen, T. Phillips[1], and C. Reed[2]

Full-Time Scientist Equivalents (SYs): 1.0

Start Date: 07/01/97   **Term Date:** 07/01/01

Problem: Pest management decisions at grain elevators are often made with little information about insect infestation levels and depend heavily on routine use of pesticides. New regulations are increasing the cost and difficulty of using pesticides, and insects are becoming resistant to insecticides. More cost-effective pest management programs are urgently needed to maintain the quality of food supply in the U.S. and our competitiveness in global markets.

Objectives: An area-wide IPM program will be developed and implemented in networks of grain elevators in Kansas and Oklahoma to improve insect pest management programs. Elevators were selected so that grain could be followed as it moved from farm to country elevator to terminal elevators and finally left the elevator network to be milled or exported. The cost and effectiveness of the current pest management program was measured at 11 elevators in Kansas and 12 elevators in Oklahoma in collaboration with Kansas State University and Oklahoma State University. A more effective, less expensive, insect monitoring-based area-wide IPM program that is less dependent upon pesticides will be developed.

Results and Impact: Pest management decisions at grain elevators are often made with little information about insect infestation levels and depend heavily on routine use of pesticides. Areawide IPM programs are being developed for implementation in elevator networks in Kansas and Oklahoma in collaboration with Kansas State University and Oklahoma State University. During 2000, we demonstrated that sampling grain for insects can increase the cost-effectiveness of pest management and that cooling grain soon after it is stored in late June or early July can be a cost-effective alternative to fumigation. This research will make more cost-effective pest management programs available to grain elevators and thus help maintain the quality of the food supply in the U.S. and our competitiveness in global markets.

Using insect population growth models to forecast when pest management is needed can reduce the cost of insect pest management by reducing the number of times grain needs to be sampled to

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[1]Department of Entomology, Oklahoma State University

[2]Department of Grain Science and Industry, Kansas State University

determine insect infestation levels. During FY2000 at 28 elevators in Kansas and Oklahoma, the same grain was sampled more than once to determine insect population growth rates. We were able to establish that insect population growth rates at elevators were the same as those on farms. This means that the insect population growth models developed to predict insect populations in farm storage can be used for grain elevators. This will speed the development of an expert system for stored grain management in large grain elevators because we can build on information previously collected from smaller farm storage bins. Such an expert system will allow elevator managers to simulate the effectiveness of various pest management programs and give them access to data that we are collecting on insect infestation levels, grain quality, grain moisture and grain temperature. This expert system also will provide information on the relative cost of moving and fumigating grain, and manual or controlled aeration.

Implementing an area-wide IPM program for stored wheat will help keep insects below economically damaging levels as the wheat moves through the U.S. marketing channels. An area-wide demonstration of the cost-effectiveness of biologically-based, insect-control technologies will make adoption by the grain-storage industry more likely. Reductions in the amount of grain fumigated and fumigation frequency will reduce worker exposure and the risk of control failures due to insects developing resistance to phosphine. The area-wide IPM program will also demonstrate the feasibility of decreased use of grain protectants and, as a result, the levels of insecticide residues in domestic and exported wheat will go down satisfying consumers' and importers' requests for improvements in food safety.

Reduced pesticide use also will conserve natural enemies that are frequently present in the grain. If reductions of pesticide residues, reduced fumigation, area-wide suppression of insect infestation levels, and lower insect control costs are achieved, our work in the grain marketing system will strengthen the competitiveness of the United States in wheat-export markets.

Goals for 2001 and 2002:

Specific tasks for 2001 will be to facilitate adoption of areawide IPM practices by elevator managers by sampling all of the bins at their elevator with a vacuum probe and providing them with information on grain temperature, and insect infestation and damage levels for each bin. Information will be provided on a 1 page diagram of the bin layout for easy access. Managers will be interviewed to determine how this information was used in making pest management decisions. Results of the first 4 years of the project, will be used to illustrate the advantages of alternative pest management decisions. Elevators outside the elevator network monitored during the first 4 years of the project will now be included in the project.

Specific tasks for 2002 will be to repeat the program used in 2001 to encourage the continued use of areawide IPM by elevator managers.

Summary of 2000 Publications/Patents:

01. Hagstrum, D. W., Reed, C. and Kenkel, P. Management of stored wheat insect pests. Integrated Pest Management Reviews. 1999. v. 4: p. 127-142.

For More Information on this Project Contact:

Dr. David Hagstrum
Telephone - 1-800-627-0388 or (785) 776-2718
FAX - (785) 776-2792
email - hagstrum@gmprc.ksu.edu

ENGINEERING RESEARCH UNIT

The mission of the Engineering Research Unit is to develop rapid automated technologies and instrumentation for the assessment of grain quality and end-use characteristics and to improve grain handling and storage methodology in order to minimize breakage, dust emissions and quality losses. Specific projects for this Unit include:

CRIS - 5430-43440-003-00D   Improved Handling and Storage Systems for Grain Quality Maintenance and Measurement

CRIS - 5430-44000-009-00D   Objective Grading and End-Use Property Assessment of Single Kernels and Bulk Grain Samples

Improved Handling and Storage Systems for Grain Quality Maintenance and Measurement

Project Leader: M. Casada   **Investigators:** M. Casada and Vacant

Full-Time Scientist Equivalents (SYs): 1.6   **Net Funding to Location per Year:** $ 436,364

Start Date: 06/14/96   **Term Date:** 06/13/01

Problem: The production and marketing of grain is a major component of the U.S. agricultural economy, food production and export trade. Improved grain drying, storing, aerating, and handling while maintaining quality and energy efficiencies will increase food wholesomeness, safety, and market competitiveness. This information is useful to producers, elevator and dryer operators, equipment and facility design engineers, marketers and handlers of grain, Extension Service specialists, and government regulatory agencies.

Objectives: An important goal of this project is the development of post-harvest engineering technology for grain quality assessment, maintenance, and functional utilization with emphasis on energy conservation and personnel safety. Specific areas include the improvement of grain aeration management and practices, evaluation of water mist in controlling grain dust emissions, development of economical and compliant methods for control of grain dump pit dust emissions, validation of current procedures for predicting allowable storage times under changing temperature and moisture conditions, and development of more energy efficient methods for artificially drying shelled corn and other commodities. This research supports the national need for grain facility and worker safety where fires and explosions as a result of ineffective grain dust control and management continue to occur and where agricultural workers are frequently exposed to environments at high respiratory dust levels. Compliance and standards for atmospheric grain dust emissions from grain handling facilities are also addressed.

Results and Impact:

1. Water Mist-Grain Dust-Air Relationships. A model was developed that adequately expresses the dissipation of mist drops in air, their potential impact with other mist or dust particles, and the trajectory of both mist and dust particles in moving air streams. According to the model, the induced airflow from the nozzle spray was found to be sufficient to overcome the poor mobility of the small diameter (10 micron) water particles and transport the particles over the long distances required to effectively aid in grain dust control. The model can be used to maximize the effectiveness of dust control in grain handling environments to reduce explosion disasters such as the 135 reported grain dust explosions in a recent ten year period (1989 - 1998) that killed 17 people, injured 129, and caused $100 million of facility damage.

2. New Dump Pit Baffle is Effective at Dust Control. A cost-effective alternative to reduce and control dust emissions at grain elevator truck dump pits has been developed in cooperation with Oklahoma State University. Tests with and without the existing baffle and with two versions of the proposed baffle at the GMPRC grain dump pit showed that dump pit dust emissions could be significantly reduced with the proposed baffle. The system will minimize worker dust inhalation, personal health problems, and control dust emissions at truck dump pits with a significant installation and operating cost advantage compared to current negative air dust control methods.

3. Validation of Dry Matter Loss versus Storage Time Curves for Stored Grain. The adequacy of current procedures for predicting allowable storage times under changing temperature and moisture conditions was validated in cooperation with researchers at the University of Minnesota (UMN) and Iowa State University (ISU). Key findings were that the predicted dry matter loss vs. storage time curves were similar for predicted and measured values for both step changes and cyclical changes in temperature. This suggests that current methods are probably adequate for predicting allowable shelled corn storage time under changing temperature conditions. The primary impact of this work is that other research, extension, and facility design engineers can now be confident that the procedures previously proposed to predict allowable shelled corn storage time under changing storage temperatures are reasonably accurate.

3. Reduction of Energy Consumption Needed for Drying Grain. Energy consumption and inefficiencies while artificially drying shelled corn are too high and can be reduced through improved process efficiencies and new alternatives to direct heating of air with gas fired burners. The prototype of a new heat pump drying concept (10 bu/hr) was modified and tested at GMPRC during the 1999 harvest season in cooperation with Grain Systems Incorporated, Elm Creek, NE (CRADA) and with input from DOE, Allied Signal, Inc., Kansas City, MO. In tests on shelled corn and Milo, the efficiency of the modified prototype was 20% better than any previously known heat pump dryer. The new concept has the potential to reduce the total input operating energy requirements for drying grain and other commodities by more than 60 percent, however fixed or management costs are projected to increase while gaining this improvement in operating efficiency.

4. Computer Model Developed to Predict Grain Bin Temperature. Optimizing the design and management of grain storage systems requires proper analytical tools such as validated computer models of the stored grain environment. A new computer model of the temperature and natural convection air currents in stored grain was developed at GMPRC. This model predicts temperatures anywhere in the grain storage bin based on the weather conditions and type of grain in the bin. The model will allow grain storage designers and managers to evaluate the conditions and variables that effect the stored grain quality due to factors such as survival of storage insects and fungi so those conditions can be properly controlled and managed.

Goals for 2001 and 2002:

Specific tasks in 2001 will be to:

1. Conduct air/dust/spray validation tests to confirm the mathematical models and provide fundamental data on the effectiveness of water sprays to control dust without increasing the moisture content and weight of the grain.

2. Conduct mechanical baffle tests with the revised dump pit baffle design at a cooperating country elevator in Oklahoma to determine grain dust emissions per ton of wheat (and corn) dumped and compare results to those at the GMPRC elevator.

3. Determine the particle size distribution of airborne grain dust during tests at the GMPRC elevator to document dust particles that are small enough to drift off premises as emissions and cause respiratory problems with grain workers.

4. Continue to collect, analyze, and report performances of selected grain aeration strategies. Use the collected data to validate the grain storage computer model.

Specific tasks in 2002 will be to:

1. Study the potential development of an aeration control system that maintains the moisture content of stored wheat at higher levels, but within the safe storage moisture-temperature guidelines.

2. Modify the complete temperature model for grain storage to include predictions of moisture content changes during storage.

3. Evaluate several levels of simplified grain storage models to determine the simplest level of inputs (of weather and related data) that will provide adequate prediction of grain storage temperatures.

4. Evaluate the factors affecting the efficacy of heat pretreatment for insect control prior to filling grain storage bins, and optimize heating methods for the best insect control.

Summary of 2000 Publications/Patents:

01. Casada, M.E. Adapting a Grain Storage Model in a 2-D Generalized Coordinate System to a 2-D Cylindrical System. 2000. ASAE Paper No. 00-3109 Presented at the ASAE International Meeting, Milwaukee, WI. July.

02. Steele, J.L., Shogren, M. and Brabec, D. Mixogram Analysis Guide-lines based on Mixograph Dynamics. 1999. AACC Annual Meeting. Seattle, WA. October.

03. Casada, M.E. and Alghannam, A. Aerating over-dry grain in the Northwest. Transactions of the ASAE. 1999. v. 42(6). p. 1777-1784.

For More Information on this Project Contact:

Dr. Mark Casada
Telephone - 1-800-627-0388 or (785) 776-2758
FAX - (785) 776-2792
email - casada@gmprc.ksu.edu

CRIS 5430-43440-003-00D - Specific Cooperative Agreement

Quality Oriented Marketing of Hard Winter Wheat

Investigators: J. Steele and T. Herrman[1]

Start Date: 09/30/96   **Term Date:** 08/31/99

Problem: Approximately 25 million dollars of value associated with wheat quality are not realized by Kansas producers when marketing their wheat because almost all wheat is blended while the cost of capturing that value at country elevators approaches 14 million dollars. Increased production of new Hard White Winter varieties will increase the pressure to segregate wheat at the first point of sale. As new technologies for rapid objective grain quality assessment are developed, it is vital that they be tested for potential benefits in the market channel. The Perten Single Kernel Characterization System (SKCS) 4100 instrument provides mean and distributional measures for wheat kernel weight, size, hardness and moisture content. This information, combined with single kernel NIR analyses, can be translated into flour mill performances and hence market value of the wheat. Advancement and application of this technology suggests quality segregations can be made at the first point of sale or as the grain is harvested and delivered.

Objectives: This project will investigate the potential for quality binning of Hard Red Winter (HRW) and Hard White Winter (HDWH) wheat at country elevators, the first point of sale for most of the winter wheat. The study addresses the capabilities of the elevator to quality segregate in real-time, the criteria for quality binning, and the economics of quality binning. The criteria for binning will be based on new developed technologies for wheat quality assessment. The relevance of binning based on physical property measures as reported by the Perten SKCS 4100 and the Infratech 1229 protein analysis is included in the study.

Results and Impact: The information gained during this project was used to develop commercial quality oriented marketing strategies. The first of these efforts involved using data gathered at country elevators to assess the feasibility of segregating HDWH and HRW at the same elevator. Individual simulations were run for elevators planning to receive HDWH wheat and estimated delay time and costs associated with segregating HDWH and HRW wheat were provided to elevator managers. Truck delay time associated with segregating wheat was approximately 2.5 minutes for a two leg single drive elevator during a moderate harvest day when the sampling station was positioned ahead of the scale. For a large harvest day (>60% average burden on the receiving system), the additional delay associated with segregation was 12 minutes per truck.

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[1]Department of Grain Science and Industry, Kansas State University

This project also included the identity preserved (IP) marketing of HRW wheat to Mexico. The Perten 4100 SKCS and Infra-tech 1229 were used to measure wheat quality in addition to evaluating milling and baking performance. Thirty two railcars of IP wheat were shipped to two commercial flour mills in Mexico City. Single kernel data were collected for each wheat in the blend (Canadian, Mexican, and U.S.) prior to tempering, the wheat blend before and after first temper, and after the second temper prior to first break. These data will be analyzed and correlated with first, second, and third break release data, and percent flour extraction. Additionally, a preliminary variance components analysis was performed to assess the variation between wheat delivered within a field, between fields of the same variety, between varieties delivered to a country elevator, and between elevators. These results will be reported by Tod Bramble in his Master's thesis which will be completed in May of 2001.

Goals for 2001 and 2002: This project will be completed and the final report will be made available in May 2001.

2000 Publications:

01. Baker, S., Herrman, T.J. and Loughlin, T. Segregating hard red winter wheat into dough factor groups using single kernel measurements and whole grain protein analysis. 1999. Cereal Chem. 76(6):884-889.

02. Baker, S., Herrman, T.J. and Loughin, T. Use of regression and discriminant analyses to develop a quality classification system for hard red winter wheat. 1999. Cereal Chem. 76(6):890-893.

03. Herrman, T. and Boland, M. Segregation strategies. 1999. Feed & Grain. Feb/March pp 20-25.

04. Herrman, T.J., Boland, M. and Heishman, A. Economic feasibility of wheat segregation at country elevators. 1999. Second Annual National Wheat Industry Research Forum pp 13-16.

05. Herrman, T.J. Identity preservation: operational aspects of a value-enhanced marketing strategy. 1999. GEAPS 70th Annual International Technical Conference and Exposition pp. 59-70. March 6-9, 1999 Tampa, FL.

For More Information on this Project Contact:

Dr. Floyd Dowell
Telephone - 1-800-627-0388 or (785) 776-2753
FAX - (785) 776-2792
email - fdowell@gmprc.ksu.edu

CRIS 5430-43440-003-00D - Specific Cooperative Agreement

Improved Baffle Design and Dust Control Procedures for Dump Pit Grain Handling

Investigators: M. Casada, R. Noyes[1], P. Kenkel[1], and G. Cuperus[1]

Start Date: 09/22/95   **Term Date:** 09/21/00

Problem: The production and marketing of wheat, corn, rice, sorghum, soybeans and other grain and seed crops is a major component of the U.S. agricultural economy, food production industry and export trade. Worker safety, grain dust explosions and fires are a persistent concern in commercial grain handling facilities. Energy requirements for conventional dust control using air aspiration techniques are excessive in many elevators. Developing economical compliance methods for EPA and OSHA standards are critical for continued economical operation of grain handling facilities. Grain truck pit unloading sites are frequently open or exposed in ways which permit atmospheric emissions to occur during use. Dust that becomes airborne during grain unloading affects worker and facility safety and EPA regulatory standards. Truck dump dust emissions are affected by facility design, grain characteristics, and wind conditions that are not well documented.

Objectives: This research utilizes the research elevator grain handling and research facilities at the ARS GMPRC, Manhattan, KS. The primary objective was to measure typical dump pit dust emission levels and develop a cost effective mechanical dump pit baffle system to reduce emissions to insure compliance with EPA environmental and OSHA worker safety requirements. Specific study objectives were to: I.) Test wheat and corn dust emissions at the GMPRC facility with conventional dump pit baffles, then with conventional baffles removed; II) Design and lab-test a prototype mechanical `Z' baffle design for truck dump pits such that it can be easily adapted to fit most elevators; III) Finalize the prototype design, install and test a working version of the `Z' baffle system at the GMPRC elevator facility on wheat and corn. Document dust emission levels to compare with Phase I; IV) Test the `Z' baffle system at a commercial elevator in Oklahoma on wheat; and V) Develop and test a small negative pressure dust collection system specifically designed to control dust emissions from the `Z' baffle system to provide increased dust emission control at country elevators.

Results and Impact: Results showed that the fixed and pivoting Z baffle steel was too thin and the hanger brackets needed modification. The design was revised to correct these problems and the remaining twenty modules were installed. Dust emission data obtained using the new mechanical Z baffle design were compared with data from the conventional dump pit dust control baffles and with no dust control in the dump pit. Although final data analysis has not been completed, the new Z baffles were visibly better. Phase III tests visibly reduced dust during

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[1]Department of Agricultural Engineering, Oklahoma State University

closed door tests, and airborne dust captured in high efficiency dust filter bags was considerably less. Elevator managers and superintendents will be able to take the final modular design and have economical dump pit baffle assemblies fabricated at local metal shops. For increased dust control, a small efficient negative air cyclone system can be used to return collected grain dust back to the grain flow stream. This mechanical dump pit baffle dust control system will minimize worker dust inhalation, personal health problems, and control dust emissions with a significant installation and operating cost advantage compared to conventional baffles and high horsepower full aspirated systems. This design will provide an "affordable", reliable, low maintenance, long term dust control system for truck and railcar dumping that can be adapted to grain and milling facilities.

Goals for 2001 and 2002: This project ended September 30, 2000. OSU will continue research to address the remaining objectives and a final report will be made available after this work is completed.

2000 Publications: None at this time.

For More Information on this Project Contact:

Dr. Mark Casada
Telephone - 1-800-627-0388 or (785) 776-2758
FAX - (785) 776-2792
email - casada@gmprc.ksu.edu

CRIS 5430-43440-003-00D - Specific Cooperative Agreement

Confirmation of Carbon Dioxide from Shelled Corn Exposed to Changing Conditions

Investigators: J. Steele, W. Wilcke[1], C. Bern[1], and R. Meronuck[1]

Start Date: 09/27/96   **Term Date:** 06/30/00

Problem: If grain is stored at moistures higher than that recommended for safe storage, microbial activity can cause losses in grain dry matter and quality. Deterioration and loss of dry matter during artificial drying or long term storage is a direct loss to producers and consumers with the additional risk of toxic substance development or insect infestation. Carbon dioxide production measurements were found to be successful in predicting allowable long term storage times, however the validity of these predictions for changing grain temperatures had never been verified. Confirmation of the test methods is needed for changing temperature and moisture conditions and to confirm responses with current hybrids, harvest conditions, and methods.

Objectives: This research will examine if the previous ARS developed data and methods for predicting allowable shelled corn storage times are adequate for sound management and facility design decisions. Since, long term grain storage and quality maintenance decisions are based on these data, it is vital that their validity under changing temperature conditions be confirmed.

Results and Impact: Corn harvested from a single field near Ames, IA was split between the University of Minnesota (UMN) and Iowa State University (ISU) to conduct corn storability tests at both locations. UMN researchers used a near-infrared spectrometer to measure carbon dioxide concentrations in air that passed through 300-g samples of corn, while ISU researchers measured production by weighing tubes of material that absorbed carbon dioxide from the air passing through 1-kg samples of corn. Both procedures reflect cumulative carbon dioxide production, which is an index of corn dry matter loss. During 2000, the UMN researchers conducted preliminary work comparing predicted and experimentally determined allowable storage times for shelled corn stored under changing moisture conditions. ISU researchers conducted several more storage tests under changing temperature conditions. Again, key findings were that the general shapes of predicted dry matter loss vs. storage time curves were similar for predicted and measured values for step changes in moisture, and for both step changes and cyclical changes in temperature. This indicates that currently used methods for predicting allowable shelled corn storage time under changing temperature and moisture conditions are generally adequate. The primary impact of this work is that other research, extension and facility design engineers can now be confident that the procedures previously proposed to predict allowable shelled corn storage time under changing storage temperatures and moistures are reasonably accurate.

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[1]Department of Agricultural Engineering, University of Minnesota

Goals for 2001 and 2002: This project is completed.

2000 Publications: None at this time.

For More Information on this Project Contact:

Dr. Floyd Dowell
Telephone - 1-800-627-0388 or (785) 776-2753
FAX - (785) 776-2792
email - fdowell@gmprc.ksu.edu

CRIS 5430-44000-009-00D

Objective Grading and End-Use Property Assessment of Single Kernels and Bulk Grain Samples

Project Leader: F. Dowell   **Investigators:** F. Dowell and Vacant

Full-Time Scientist Equivalents (SYs): 2.4   **Net Funding to Location per Year:** $ 699,748

Start Date: 02/01/97   **Term Date:** 01/31/02

Problem: The production and marketing of grain are major components of the U.S. agricultural economy, food production and export trade. Improved utilization and market efficiencies with objective quality, functionality and grain grade assessments will increase food wholesomeness, safety, and market competitiveness. For example, accurate, rapid detection of attributes could assist in marketing or segregating genetically modified organisms or detecting food safety concerns. This information is particularly useful in evaluating grain prior to purchase or trade in market channels. Single kernel assessments are needed to detect defects that may be present in only a small percentage of kernels or to detect mixtures of contrasting quality characteristics. New technology developed through this research will provide the Federal Grain Inspection Service (FGIS) with several options for providing additional objective quality assessments of grain along with official grade services and thereby improve their services and operating efficiencies. These objective assessments of grain quality are useful to producers, breeders, growers, grain handlers, marketers, millers, bakers, and government agencies such as the Extension Service, FGIS, the Food Safety Inspection Service, and the Occupation and Safety Health Administration.

Objectives: The main goal of this research is to develop sensors and instrumentation for objective grading, on-line measurement, and end-use property assessment of single kernels or bulk grain samples. Specific issues being addressed include: rapid assessment of physical properties such as kernel size; near-infrared (NIR) measurements of single kernel attributes such as fungal damage or internal insects; machine vision assessment of bread crumb grain; objective detection of wheat kernel defects in FGIS Line Slide images; objective analysis of dough mixing; methodology to relate physical properties of wheat to milling energy and optimum mill settings; quality oriented marketing of hard winter wheat; and use of single kernel characterization system (SKCS) data for commercial milling of SRW, SWH and HRS wheat.

Results and Impact:

1. Optimization of a Simple Test for Wheat Color Class Confirmation. The Kansas Wheat Commission requested that ARS develop simple, rapid, safe, and objective procedures for differentiating between red and white wheat color classes. With their funding support, we optimized the procedure for soaking kernels in sodium hydroxide, resulting in a rapid change in

seed color that makes color classification simple and accurate. This color classification test is now commercially marketed and used by the wheat industry and inspectors to determine wheat color class. This simple procedure can help promote the adoption and segregation of hard white wheat and help expand our hard white wheat export markets.

2. Detection of Insect Infestation Inside Wheat Kernels. Official grading procedures do not detect and measure the presence of insect pests inside wheat. We utilized a kernel singulator and near-infrared system that allows automated scanning of single kernels (commercially available SKCS 4170 from Perten Instruments). Calibrations were developed to identify kernels containing large larvae and pupae, and these calibrations were installed on commercial instruments used by flour mills. Large larvae can be detected with greater than 90% accuracy. This technology will help managers of storage facilities and mills make informed decisions concerning fumigation, and lead to reductions in insect damage and insect fragments in flour.

3. Automated Detection of Aflatoxin and Fumonisin. Aflatoxin and fumonisin are carcinogens found in corn, and rapid detection means are needed to insure a safe food and feed supply. In cooperation with scientists in Peoria, IL, and Albany, CA, we studied the use of near-infrared (NIR) spectroscopy to detect these toxins, and the fungi that produce them. Results showed that we can detect low levels of toxin in single kernels using reflectance or transmittance spectroscopy. This research could result in rapid senors for detecting toxins in samples, or sensors that can rapidly detect and segregate all individual kernels before they are used for food or feed purposes.

4. Affect of Sorghum Kernel Size on Feeding Efficiency. There is industry interest in increasing sorghum seed size, however, no assessment of increased size on feed components or digestibility has been made. In cooperation with KSU researchers, we investigated the use of near-infrared spectroscopy (NIRS) to measure these attributes. Crude protein was measurable by NIRS, with ground sample giving better results than whole seeds. These results showed that NIRS can be used to rapidly determine sorghum attributes and may provide the sorghum industry with a rapid screening tool.

5. Detection of Insect Hosts that Carry Parasitoid Wasps. Parasitoids wasps are naturally occurring enemies of certain species of weevil and fly insect pests. Restrictions on pesticide usage and resistance of insects to pesticides requires that alternative pest control means be developed and parasitoid wasps may represent an important control option. In cooperation with entomologists in Manhattan, KS, we developed NIRS procedures to detect parasitoid wasps in wheat kernels infested by weevils or in fly paparia. For both weevil and fly parasitoids, viable parasitoids could be detected up to 1 week before emergence. Rapid, non-destructive detection of these natural enemies of pests could lead to development of sorting systems for detecting and sorting large quantities of parasitoids for mass release in biological control applications.

Goals for 2001 and 2002:

Specific tasks in 2001 will be to:

1. Continue with the development and implementation of NIR, machine vision, and mechanical sensors for measuring grain and grain product attributes.

2. Investigate other sensors such as those utilizing biological organisms or lasers for measuring grain attributes.

3. Continue development of a low-cost NIR system for detecting single kernel attributes and sorting based on these attributes.

4. Continue investigating other single kernel quality measurements such as protein and starch quality, and detection of transgenic attributes.

5. Continue with modifications and design for single kernel corn crushing.

6. Continue image acquisition, calibration and testing of the GrainCheck 310, a commercial image analysis instrument, to determine performance and potential as an aid to grain inspectors. We plan to develop the "best" GC 310 calibration which will separate dark hard vitreous (DHV) kernels from non-DHV wheat kernels and to develop the "best" GC 310 calibration which will separate hard vitreous and amber colored (HVAC) kernels from non-HVAC wheat kernels.

7. Continue cooperating with industry and other researchers to investigate single kernel NIRS to measure insect characteristics and quality of other commodities.

Specific tasks in 2002 will be to:

1. Develop high-speed single kernel sensing and sorting instruments utilizing NIR, machine vision, and/or mechanical sensors.

2. Investigate other sensors such as those utilizing biological organisms or lasers for measuring grain attributes.

3. Complete development of a low-cost NIR system for detecting single kernel attributes and sorting based on these attributes.

4. Continue investigating other single kernel quality measurements such as protein and starch quality, and detection of transgenic attributes.

5. Investigate engineering aspects of rearing, detecting, sorting, shipping, releasing, and maintaining parasitoids for biological control of stored-grain pest insects.

Summary of 2000 Publications/Patents:

01. Burks, C.S., Dowell, F.E. and Xie, F. Measuring fig quality using near-infrared spectroscopy. Journal Stored Products Research. 2000. v.36 p. 289-296.

02. Dowell, F.E. Differentiating vitreous and nonvitreous durum whea kernels by using near-infrared spectroscopy. Cereal Chem. 2000. v. 77(2). p.155-158.

03. Dowell, F.E., Throne, J.E., Baker, J.E., Broce, A.B. and Xie F. Detection of parasitized insects for biological control applications by using NIR spectroscopy. ASAE Paper No. 003090. 2000. 11 pp.

04. Dowell, F.E., Throne, J.E., Wang, D. and Baker, J.E. Identifying stored-grain insects using near-infrared spectroscopy. Journal Economic Entomology. 1999. v. 92(1). p. 165-169.

05. Kramer, K.J., Morgan, T.D., Throne, J.E., Dowell, F.E., Bailey, M. and Howard, J.A. Transgenic avidin maize is resistant to storage insect pests. Nature Biotechnology. 2000. v. 18. p. 670-674.

06. Wang, N., Zhang, N., Peterson, D.E. and Dowell, F.E. Testing of a spectral-based weed sensor. ASAE Paper No. 003127. 2000. 13 pp.

07. Wang, N., Zhang, N., Sun, Y., Peterson, D.E. and Dowell, F.E. Development of a spectral-based weed sensor. ASAE Paper No. 993037. 1999. 9 pp.

For More Information on this Project Contact:

Dr. Floyd Dowell
Telephone - 1-800-627-0388 or (785) 776-2753
FAX - (785) 776-2792
email - fdowell@gmprc.ksu.edu

CRIS 5430-44000-009-00D - Specific Cooperative Agreement

Automatic Control of an Instrumented Two-Roll Mill

Investigators: J. Steele, C. Spillman[1], and E. Haque[2]

Start Date: 09/30/96   **Term Date:** 09/19/00

Problem: Small profit margins and increased competition in flour production are continuing to drive research oriented toward being more cost effective and efficient.

Objectives: This research will test the potential of extracting meaningful mill performance predictions from data obtained from the Perten Single Kernel Characterization System (SKCS). If successful, such predictions will assist millers in making mill performance predictions in the market channel and better mill settings at the roller mill (roll gap, roll speeds and feed rate for first-break) thus enabling improved grain utilization and profitability in milling operations. The research is expected to advance automatic control and optimization of flour milling in harmony with availability of new, rapid, and objective assessments of grain quality in the market channel.

Results and Impact: NIR-particle size calibrations and predictions of the amounts of the various sizes of flour particles produced during milling showed that specific wheat class models performed better than an all-wheat class model; log (1/R) models performed better than Kubelka-Munk linearized models, models that used averaged spectra performed better than those that used non-averaged spectra, and models that used unit area normalization alone or in combination with other pretreatments performed better than those that did not use unit area normalization. This research will assist millers in making mill performance predictions in the market channel and optimizing mill settings in real-time at the roller mill (roll gap, roll speeds and feed rate) for first-break milling. This will lead to improved grain utilization and profitability in milling operations.

Goals for 2001:

This project was terminated in 2000.

2000 Publications:

01. Pasikatan, M.C., Haque, E., Keller-McNulty, Steele, J.L., Fang, Q., Spillman, C.K. and Gao, W. 1998. Single kernel wheat physical properties and first-break grinding. ASAE Paper MC98-137. St. Joseph, MI.

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[1]Department of Biological and Agricultural Engineering, Kansas State University

[2]Department of Grain Science and Industry, Kansas State University

02. Pasikatan, M.C., Steele, J.L., Milliken, G.A., Spillman, C.K. and Haque, E. 1999. Particle size distribution and sieving characteristics of first-break ground wheat. ASAE Paper MC99-129. St. Joseph, MI.

03. Pasikatan, M.C., Steele, J. L., Spillman, C.K., Haque, E. and Higgins, J.J. 1999. Representative sampling of first-break ground wheat. ASAE Paper 99- 6017. St. Joseph, MI.

For More Information on this Project Contact:

Dr. Floyd Dowell
Telephone - 1-800-627-0388 or (785) 776-2753
FAX - (785) 776-2792
email - fdowell@gmprc.ksu.edu

CRIS 5430-44000-009-00D - Specific Cooperative Agreement

Identification of Wheat Quality Characteristics Using Single Kernel Spectral Analysis

Investigators: F. Dowell and N. Zhang[1]

Start Date: 09/30/96 **Term Date:** 08/31/00

Problem: Quality characteristics, such as fungal invasion or insect damage, can affect only a few kernels in a large sample, but those kernels can affect the entire lot or overall quality and are frequently difficult to detect in bulk samples. In addition, needed protein quality and quantity can also vary significantly from kernel to kernel. Thus, a method to rapidly and automatically detect wheat quality attributes on a single kernel basis is needed.

Objectives: This research will determine the potential of a Single Kernel Characterization System (SKCS) fitted with a near infrared (NIR) detector to measure the single kernel quality of wheat samples. In addition, work will also focus on other potential tests that can discriminate between hard white and hard red wheat samples. If successful, this information will assist buyers and sellers of wheat to market wheat at its highest level of end-use performance. The research is expected to advance the application and use of new, rapid and objective assessments of grain quality in the market channel.

Results and Impact: The Kansas Wheat Commission requested that we develop a test to rapidly, economically, safely, and objectively determine wheat color class. Thus, we developed standard procedures that include soaking kernels in sodium hydroxide, which accentuate red and white color class differences. This standard test was transferred to industry and a test kit is being commercially marketed. This rapid, simple test is now used by grain buyers, inspectors, and researchers to objectively determine wheat color class.

Goals for 2001: This project is completed.

2000 Publications:

01. Wang, N., Zhang, N., Peterson, D.E. and Dowell, F.E. Testing of a spectral-based weed sensor. 2000. ASAE Paper No. 003127. 13 pp.

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[1]Department of Biological and Agricultural Engineering, Kansas State University

For More Information on this Project Contact:

Dr. Floyd Dowell
Telephone - 1-800-627-0388 or (785) 776-2753
FAX - (785) 776-2792
email - fdowell@gmprc.ksu.edu

CRIS 5430-44000-009-00D - Specific Cooperative Agreement

Use of SKCS Data for Commercial Milling of SRW, SWH, and HRS Wheat

Investigators: J. Steele and C. Deyoe[1]

Start Date: 09/26/97   **Term Date:** 08/31/99

Problem: Simple, reliable quality analysis techniques are needed in order to assist with the marketing of wheat. Such systems are of a distinct advantage to producers and grain handlers because they will allow the market to determine the true value of sample based on prediction of their end-use performance.

Objectives: The Perten SKCS 4100 provides mean and distributional measures for wheat kernel weight, size, hardness and moisture content. The SKCS measures were used in combination with test weight to develop a mill performance model for Hard Red Winter (HRW) wheat. The model and predictions were not valid or useful for other classes of wheat. In this study, the mill performance model will be tailored to commercial mill performances for Soft Red Winter (SRW), Hard Red Spring (HRS), and Soft White (SWH) wheat through collection and evaluation of performance data from samples milled at commercial mills.

Results and Impact: SKCS technology and the mill performance prediction models developed in this research have been demonstrated to potential users. An economic analysis estimates that milling models which utilize the SKCS data could lead to increased profits for commercial mills approximating 2,000 - 4,000 dollars per day. Models have been formally presented at various short courses in the US and in several foreign countries. Constraints for adoption of the technology are related to exposure, SKCS cost, knowledge of modeling, and procedures to adapt the model to a specific commercial mill and wheat class.

Goals for 2001: This project is completed.

Publications: None at this time.

For More Information on this Project Contact:

> Dr. Floyd Dowell
> Telephone - 1-800-627-0388 or (785) 776-2753
> FAX - (785) 776-2792
> email - fdowell@gmprc.ksu.edu

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[1]Private Consultant

CRIS 5430-44000-009-00D - Specific Cooperative Agreement

Automated Detection of Single Kernel Grain Attributes

Investigators: F. Dowell and D. Wang[1]

Start Date: 10/01/00   **Term Date:** 09/30/01

Problem: Postharvest grain losses due to pests and poor storage practices total more than $1 billion per year in the United States. Grain is inspected for the presence of insect infestations to minimize losses associated with insect damage during storage and transportation in both domestic and export markets. U.S. standards consider wheat to be infested if >2 live insects injurious to wheat are found in a 1-Kg sample. In addition, inspectors consider wheat U.S. Sample Grade if >32 insect-damaged kernels are found in a sequential sampling of a total of 100 g of wheat. These labor-intensive inspection procedures identify the presence of adult insect outside the wheat kernels but may not detect immature insects developing within kernels. Grain samples may contain hidden larvae although no adult insects are detected at the time of inspection. The hidden infestations can cause serious quality losses during subsequent storage and transportation. Thus, a method to rapidly and automatically detect insect infestation both outside and inside of wheat is needed.

Objectives: Near-infrared (NIR) spectroscopy is commonly used to determine bulk-sample wheat quality characteristics such as protein or moisture. More recently, researchers have shown that NIR spectra from single kernels can be used to determine single kernel protein content, hardness, color class, scab, vitreousness, and internal insects. All of the above single-kernel NIR research was conducted using spectrometers that obtained spectra from single hand-placed kernels, or from a NIR diode-array spectrometer integrated with at single kernel characterization system (SKCS 4170). While hand-placed kernels or the automated SKCS 4170 can detect presence of internal insects, neither is practical for field applications. Thus, the main goal of this project is to develop an economically feasible NIR system for detecting internal insects before or after storage, before milling, and at export.

Results and Impact:

An economically feasible NIR system with a kernel feeding and sorting system for detecting internal insects in wheat is being developed. This system has functions of automatically collecting reflectance spectra from single-kernels, automatically detecting the presence of insect infestation inside each kernel based on developed classification models, and automatically sorting the kernels into insect infested or sound kernels. The development of an economically feasible NIR system

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[1]Department of Biological and Agricultural Engineering, Kansas State University

for detecting internal insects could be particularly useful for determining food quality and should be useful to processors, millers, marketing specialists, grain graders, breeders and producers.

Goals for 2001 and 2002:

Specific tasks in 2001 and 2002 include completion of the development of the sorting prototype and production of needed calibrations for its operation.

Publications: None at this time.

For More Information on this Project Contact:

Dr. Floyd Dowell
Telephone - 1-800-627-0388 or (785) 776-2753
FAX - (785) 776-2792
email - fdowell@gmprc.ksu.edu

GRAIN QUALITY AND STRUCTURE RESEARCH UNIT

The mission of the Grain Quality and Structure Research Unit is to identify and evaluate the chemical, physical, and structural grain characteristics that govern grain quality and functional properties, and to develop and evaluate instrumental methods that can be used to rapidly characterize grain quality in the market channels. A key component of this Unit is the Hard Winter Wheat Quality Laboratory that was established by Congress in 1937. Specific research projects for this Unit include:

CRIS - 5430-44000-010-00D   Characterization of Grain Biochemical Components
                                   Responsible for End-Use Quality

CRIS - 5430-44000-011-00D   Determination and Characterization of Wheat Quality
                                   (Hard Winter Wheat Quality Laboratory)

CRIS 5430-44000-010-00D

Characterization of Grain Biochemical Components Responsible for End-Use Quality

Project Leader: G. Lookhart

Investigators: O. Chung, G. Lookhart, D. Bechtel, L. Seitz, and M. Tilley

Full-Time Scientist Equivalents (SYs): 3.1

Net Funding to Location per Year: $ 636.355

Start Date: 07/05/99

Term Date: 07/04/04

Problem: Wheat bread is a major commodity in the world. Millions of loaves per day are produced in automated bakeries. The more automated a process becomes, the less opportunity for people operating the bakery to make changes needed due to variations in wheat flour properties. Since doughs are made in 6,000 to 10,000 pound batches, if the dough can not be used because of stickiness or because it fails the mix time requirement, the bakery has to throw out that batch and clean the entire system. This is very costly in terms of ingredients and time. Rapid methods to predict wheat flour quality, without expensive and time-consuming tests such as test baking are urgently needed for the baking industry. Furthermore, rapid prediction methods for breadmaking quality would enhance the U.S. export of hard winter wheats, because international buyers of U.S. wheat want to know what quality they are receiving prior to purchase.

Objectives: The three components known to have an effect on the baking quality of wheat flour are starch, proteins, and lipids. Scientists in this unit analyze these components. The first step in understanding these roles is to be able to accurately and quickly measure the amounts, sizes and types of each fraction. Our goals are to develop rapid methods of analyzing the components of each fraction and to determine the types of lipids and the starch and protein size distributions in wheat in order to establish which populations are important in bread making. Additionally, we are identifying volatile compounds from breads that are associated with bread quality. Some volatiles are associated with flavors, while others might be used to monitor the progress of various steps during production of bread in bakeries.

Results and Impact:

1. Characterization of Glutenin Proteins from International Wheat Lines with Unique Properties. Gluten is the essential component in wheat for making bread and is responsible for the development of the cohesive dough that is required to form a loaf of bread and other products. Glutenins are one of the main components of gluten and can be separated into two classes - the high molecular weight glutenins (HMW-GS) and the low molecular weight glutenins (LMW-GS). HMW-GS are directly related to the quality of bread. There are 4-6 HMW-GS in bread wheat and the number and composition of each HMW-GS are important in determining the

bread making quality of a given wheat cultivar. For example, the HMG-GS 5 found in the wheat variety Karl is associated with the production of high quality bread. The recently discovered HMW-GS 43 and 44 in *Triticum tauschii* are related to reduced mixing time and better baking quality. Work on determining the sequence of DNA that codes for HMW-GS 43 and 44 from *T. tauschii* has been completed.

2. Comparison of Digital Image Analysis Data to a Laser Light Diffraction Instrument for Analysis of Starch Size Distributions. Two methods of measuring starch size distributions were compared, digital image analysis and laser diffraction. Each method has advantages and disadvantages, but the two methods have never been compared to determine if they provide similar results. A laser light diffraction system provides rapid analysis of large numbers of particles and generates average values for the numbers of particles of different sizes (based on volumes). Size distributions obtained from image analysis are very slow, provides accurate data on each particle, but can not be directly compared to those of the laser light instrument because image analysis data is based on the number of particles counted. Data obtained from image analysis was reprocessed to correct for starch granules touching the edge of the field of view and then converted to volume average data. Comparison of a laser diffraction method to image analysis suggests that the diffraction method measures wheat type A starch granules as shaped somewhere between a sphere and a sphere that had been flatten on two opposite sides. The smaller type B granule population, as measured by laser diffraction, tended to have a smaller diameter than those measured by image analysis. The image analysis method will be used to calibrate the laser light method so that routine measurements of starch will be used to help predict wheat quality and improve bread quality for breeders, bakers, and consumers.

3. Wheat Flour Glycolipid Analysis. Glycolipids (GL) are compounds in nature that have a carbohydrate or sugar component and a lipid or fat component bound together in the same molecule. The amounts of two major glycolipids (monogalactosyldiglycerides, MGDG, and diglactosyldiglycerides, DGDG) in wheat flour were measured and comparison between different separation and detection systems were made. Free lipids (FL) were extracted from wheat flour samples and dissolved in hexane. Absorbance (log 1/T) values were measured using a scanning spectrophotometer and results were used to develop calibration models for estimating flour FL content and GL and DGDG contents. Fifty-one calibration samples were selected and the remaining twenty-one samples were used for validation. The best model for the estimation of FL contents showed cofficients of determination (R^2) of 0.95 for the calibration set and $R^2 = 0.89$ for the validation set. Glycolipid contents could be estimated by a model which had $R^2 = 0.87$ for the calibration set and $R^2 = 0.89$ for the validation set. For DGDG, the best model showed $R^2 = 0.94$ for the calibration set and $R^2 = 0.88$ for the validation set.

4. Fatty Acid Composition of Free Lipids in Hard Winter Wheats: Variety, Location, and Year Effects. The fatty acids in free lipids (FL) of flours obtained from six hard winter wheat varieties harvested at 8 locations from 1995 to 1997 in Kansas were analyzed to investigate the effects of variety, growing location, year and their interactions. Flour FL were extracted by a supercritical fluid extraction system and fatty acids were analyzed by gas chromatography. Linoleic (63%), palmitic (19%), and oleic (13%) acid were the three most abundant fatty acids in

FL on an average. Fatty acid content varied significantly depending on the year, location where the wheat was grown, and the variety. Wheats were grown under dry and irrigated conditions at one location and their flours showed no significant differences in fatty acid contents and compositions.

5. Volatile Compounds in Five Starches. Volatile compounds in commercial wheat, corn, potato, waxy corn, and tapioca starches and in laboratory-prepared wheat, corn, and potato starches were collected, separated, and identified using a purge and trap concentrator interfaced to a gas chromatograph. Hexanal was the most abundant compound in the corn and potato starches and in the laboratory-prepared wheat starch. Hexanal was the third most abundant compound in commercial wheat starch after 2-ethyl-1-hexanol and benzaldehyde. Among the volatile organics, the level of aldehydes was the highest, followed by alcohols, ketones, benzenes, esters, and terpenes. Waxy corn starch released substantially higher level of total volatiles than all other starches. Tapioca starch contained few volatiles. No alcohols were found in commercial corn starch. Terpene compounds were detected only in commercial potato, waxy corn, and tapioca starches. Many volatiles detected in wheat and corn starches also were detected in the kernels of their commercial samples.

6. Development of Fast Methods to Identify Cultivars. An ultrafast capillary electrophoretic method to characterize cereal (wheat, oats, rice, and barley) proteins and to fingerprint cultivars in less than 4 minutes was developed. Analysis of the proteins present in sorghum and maize (corn) was completed in less than 15 minutes. The ultrafast method makes it possible to meet the industrial demand of being able to identify cultivars in less than 5 minutes.

Goals for 2001 and 2002:

Specific tasks in 2001 will be to:

1. Characterize the molecular weight distribution of soluble and insoluble polymers of cereal grains and relate them to quality parameters.

    a. Protein fractions of commercially milled flours will be characterized and correlated with commercial quality parameters.

    b. Faster SDS-CE methods will be developed to characterize the glutenin polymers for quality prediction.

    c. Wheat cultivars will be characterized for size classes of starch granules and size and quantity of protein fractions and lipid components.

2. Analyze HMW-GS 43 and 44 from *T. tauschii* and compare the differences and similarities of GS 43 and 44 to normal bread wheat GS 5 and 10 or 2 and 12. Transform wheats with the genes for GS 43 and 44 and grow plants in greenhouse and check for expression.

3. Characterize the biochemical components of wheat breeder and commercial samples and develop a statistical model to predict bread quality. Data from complete analysis of starch, protein, and lipid components will be correlated in various combinations with end-use (breadmaking, pizza, and tortilla) qualities.

    a. The final corrections for perimeter-touching-edge will be completed and will allow for the routine use of the system to measuring starch quality.

    b. Research will be started on determining specific sizes of starch that influence end-use quality such bread crumb grain.

    c. Characterize lipid components in wheats and/or flours to be added for end-use quality prediction model.

4. Complete the evaluation of sensory and chemical data collected from a group of 750 samples and publications on compound-odor associations and how volatile compounds can indicate problems in stored grain caused by insects, molds, and spontaneous heating will be written.

5. Continue to provide odor vs. compound information to GIPSA/FGIS and suggest how the information could be used to aid odor assessments during grain inspections. Considerable data on volatiles in flour, doughs, bread ingredients, freshly baked breads, and freshly popped popcorn has been obtained. Complete the compilation of extensive chromatography data, identification of many compounds.

Specific tasks in 2002 will be:

1. Study the interactions of the various biochemical components (proteins, lipids, and starch) and the molecular weight distributions of soluble and insoluble protein polymers and the effects of all these parameters on end-use (breadmaking, pizza, or tortilla) qualities. All information will be used to build a statistical model to predict end-use quality. In that way, a bigger picture (total interaction) of the wheat quality puzzle will be available.

2. Grow out plants in greenhouse and continue to check for expression and gluten protein characteristics (molecular weight distributions of gliadin, soluble polymeric, and insoluble polymeric proteins).

3. Transform the genes responsible for GS 43 and 44 into red and white hard winter wheats.

4. Additional analyses will be conducted on red and white wheats to obtain more information on compositional differences that may relate to color or nutritional factors.

5. Some microscopy studies may be initiated to obtain better information on the location of the compounds in the wheat kernel.

6. Work will also be conducted on how the environment affects starch quality and lipid composition.

Summary of 2000 Publications/Patents:

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11. Chung, O.K., Dowell, F.E., Lookhart, G.L., Ohm, J.B., Bean, S.R., Steele, J.L., Seitz, L.M., Bechtel, D.B., Ram, M.S., Sayaslan, A., Wang, D., Martin, C.R., Zayas, I.Y., Hubbard, J.D., Tilley, M., Seabourn, B.W., Caley, M.S., Rengarajan, R., Downing, J.M., Park, S.H., Wilson, J.D., Baker, J.E., Throne, J.E., Flinn, P.W., Sauer, D.B., Chang, C.S., and Koeltzow, D.E. Wheat research in the U.S. Grain Marketing Research Laboratory. 2000 Annual Wheat Newsletter 46:205-219.

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16. Lookhart, G.L. and Bean, S.R. Cereal proteins: Composition of their major fractions and methods for identification. Chapter 11. *In:* Handbook of Cereal Science and Technology. K. Kulp and J.G. Ponte, Jr., Editors, 2000. p. 417-477. 2nd edition. Marcel Dekker, Inc., New York, NY.

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For More Information on this Project Contact:

Dr. George Lookhart
Telephone - 1-800-627-0388 or (785) 776-2736
FAX - (785) 537-5534
email - george@gmprc.ksu.edu

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Determination and Characterization of Wheat Quality
(Hard Winter Wheat Quality Laboratory)

Project Leader: O. Chung   **Investigators:** O. Chung, G. Lookhart, M. Tilley, and
B. Seabourn

Full-Time Scientist Equivalents (SYs): 2.9   **Net Funding to Location per Year:** $ 931,713

Start Date: 08/01/00   **Term Date:** 10/31/01

Problem: Achieving acceptable end-use quality for milling and baking is an important objective of wheat breeding programs throughout the U.S. hard winter wheat region. On average, it requires 10-14 years for a new wheat variety to be developed and enter the commercial market place. The demand for consistent quality by the domestic milling and baking industry, and an increasingly competitive export market, emphasize the need for end-use quality as a major breeding objective. The use of unadapted germplasm to enhance genetic diversity or incorporating desirable pest resistance traits into commercial varieties also requires implementation of efficient end-use quality evaluation systems. A method for screening undesirable experimental lines from breeding programs is highly desirable, and would facilitate more rapid development of those lines that would most benefit commercial markets. There is a very real need in the commercial milling and baking industry for a more accurate and rapid method for evaluation of the end-use properties of wheat and flour. For example, considerable time and expense could be saved by commercial bakeries if an online quality monitoring system could be incorporated into the dough formulation and mixing process.

Objectives: One of the main goals of this project is to extend our knowledge of the interaction of the basic components (protein, starch, lipid, and water) in a flour-water system, and to thus provide a more rapid and objective means for determining the end-use performance of a given flour sample. This new information will ultimately facilitate the increased utilization of U.S. wheat flour for new and unique commercial products, as well as in export markets. An equally important goal for this project is to develop the tools needed to segregate wheats based on quality attributes at the first point of sale. In addition, quality analysis tools that can be applied to very small samples are also needed to provide breeders with the performance evaluation of new cultivars.

Results and Impact:

1. Wheat Quality Relational Database. The wheat quality database was updated with the results from the 2000 crop year quality analyses. The web page (http://gqul.usgmrl.ksu.edu/gqu/HWWQL/HWWQLHome.htm) for the Hard Winter Wheat Quality Laboratory (HWWQL) was developed so that breeders and other industry customers could

easily access regional performance nursery data via the internet. This is a continuous process in which the database is expanded each year.

2. Establishment of Direct Dough Analysis Capabilities. Gluten protein is the main component that determines dough quality and rapid, objective technologies are needed by the milling and baking industry to assess the end-use quality properties of flour and dough prior to and during processing. We have purchased a Fourier Transform Infrared (FTIR) spectrometer and a Raman spectrometer to monitor the chemical changes in gluten proteins and other constituents during dough development. We have begun collecting data on chemical changes in the dough during development in order to compare these changes with end-use quality and performance.

3. Association of Flour Properties with Waxy Starch Content. Waxy starch contains low levels of amylose starch. The amounts of amylose present in the kernel is determined by three different waxy genes (A, B, and D). We collaborated with scientists at Kansas State University in Manhattan, KS to examine 12 soft wheat cultivars for waxy gene expression. Four cultivars missing one or more of these waxy genes were discovered, and one cultivar (Fillmore) was found to possess a null allele at the B genome locus. This information assisted colleagues at the USDA-ARS Soft Wheat Quality Laboratory in understanding starch properties such as amylose content, pasting characteristics and gel strength, and their effects on the properties of this soft wheat cultivar.

4. Prediction of Breadmaking Quality Using Simple, Rapid Cereal Testing Instruments. Data obtained in our laboratories showed significant correlations of gluten quality parameters by Glutomatic System, starch pasting properties by Rapid Visco Analyser, and mixing properties by Mixograph with breadmaking quality. Gluten contents and hydration amounts were highly correlated with water absorption. In addition, gluten parameters were significantly correlated to kernel hardness. One of the most difficult challenges in mixograph usage is to find the optimum water absorption in a given flour. Flour protein content (FP) and near-infrared hardness scores or FP and gluten parameters could predict mixograph water absorptions, showing R^2 values of 0.842 or 0.814, respectively, by multiple regression analysis. For our set of 72 wheat samples, computer-analyzed mixograph parameters were significantly correlated to conventional parameters. Computer, analyzed mixograph midline peak times and bandwidths at 6 min were highly correlated to conventional mixograph mix times and mixing tolerances, respectively. Flour pasting temperatures complemented FP in predicting loaf volumes. The ratios of FP to pasting temperatures had a significant curvilinear relationship with loaf volumes showing an R^2 of 0.725.

5. Determination of Kernel Size Impact on Flour Yields and Quality. Grain physical characteristics such as kernel size are major factors affecting milling properties of wheat, the first critical process determining performance. We separated large and medium kernels by kernel sizing methods and evaluated milling performance for each wheat sample. Large kernels showed higher flour yield but lower protein contents within a variety, although variance among varieties was larger than variance between large and small kernels for protein. These results demonstrated the importance of quality-based breeding for wheat cultivars with more large kernels, as segregating

wheat cultivars or wheats based on kernel sizing can increase flour yields which is of importance to the milling industry.

Goals for 2001 and 2002:

Specific tasks in 2001 will be to:

1. Continue with the study of chemical events during the dough development process. Mixing research will be done using samples varying widely in rheological properties. Flour will be mixed with water and scanned in the near-infrared (NIR) and mid-infrared (MIR) throughout the mixing process to determine the fundamental chemical bonds responsible for end-user dough characteristics. Quality prediction systems will be developed using NIRSystems near-infrared (NIR) reflectance/transmittance.

2. Utilize fourier transform infrared (FTIR) and Raman spectroscopy to study the protein, starch and lipid interactions in the presence of water and as they are mixed in order to provide basic chemical information on the rheology of flour/water dough systems. Mid-infrared wavelengths critical to monitoring dough rheology will be extrapolated to the NIR so that industry personnel and researchers may easily utilize the results of this study.

3. Investigate the effects of variation of kernel hardness and weight on milling and baking properties. We will continue to study the relationships between wheat physical characteristics and end-use properties, which may be used to segregate wheats based on quality.

4. Continue the Congressionally mandated activity of the Hard Winter Wheat Quality Laboratory in evaluating the end-use quality of wheat breeding lines. Standard tests will be conducted to evaluate wheat quality and end-use performance such as physical grain tests, milling, mixing, and baking tests, in addition to the characterization of biochemical quality determinants.

5. Continue our collaborative efforts with the Wheat Quality Council, U.S. Wheat Associates, various state wheat commissions, Kansas State University, and the American Institute of Baking in evaluating the quality of U.S. hard winter wheats for domestic and export customers and in developing of techniques that can predict the end-use quality and performance of wheat shipments.

6. Continue to update the quality prediction database by the removal of obsolete or undesirable/unnecessary quality parameters and the addition of new quality parameters in order to better predict end-use performance. Fine-tuning and minor modifications will be an on-going process for as long as the database is used.

Specific tasks in 2002 will be to:

1. Expand quality testing for non-bread products as requested by our customers whenever possible.

2. Develop methods utilizing available technology for the detection of genetically modified (GMO) crops and ingredients derived from them in processed baked goods.

3. Continue to conduct the standard tests to evaluate wheat quality and end-use performance such as physical grain tests, milling, mixing, and baking tests, in addition to characterization of biochemical quality determinants.

4. Continue our collaborative efforts with the Wheat Quality Council, U.S. Wheat Associates, various state wheat commissions, Kansas State University, and the American Institute of Baking in evaluating the quality of U.S. hard winter wheats for domestic and export customers along with the development of quality predictive techniques.

5. Continue to study the relationships between wheat physical characteristics and end-use properties, which may be used to segregate wheats based on quality.

6. Add graphic images of the mixograph curve for each wheat line in the database for the next distribution of the database, as well as an interface for user-selected statistical analyses. We will remove obsolete or undesirable/unnecessary quality parameters and add new quality parameters in order to better predict end-use quality.

7. Continue to improve the predictive equations for quality factors by using more up-to-date multivariate prediction methods and our expanding database until the predictability is high enough for industry use.

8. continue to investigate the effects of the variation of kernel hardness and weight in a wheat sample on milling and baking properties.

Summary of 2000 Publications/Patents:

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For More Information on this Project Contact:

Dr. Okkyung (Okky) Kim Chung
Telephone - 1-800-627-0388 or (785) 776-2703
FAX - (785) 537-5534
email - okchung@gmprc.ksu.edu

PLANT SCIENCE AND ENTOMOLOGY RESEARCH UNIT

The mission of the Plant Science and Entomology Research Unit is to develop multiple disease and insect pest resistant wheat and alfalfa germplasms. In addition, this Unit is actively involved in the development of DNA markers for both pest resistance and quality traits. These markers are short pieces of genetic material that can be used to determine if new varieties carry specific pest resistance or quality traits. Specific research projects for this Unit include:

CRIS - 5430-21220-004-00D   Genetic Enhancement of Wheat and Alfalfa for Resistance to Multiple Biotic Stress

Genetic Enhancement of Wheat and Alfalfa for Resistance to Multiple Biotic Stress

Project Leader: D. Skinner

Investigators: D. Skinner, G. Brown-Guedira, J. Fellers, and two vacant positions are being filled

Full-Time Scientist Equivalents (SYs): 5.0   **Net Funding to Location per Year:** $ 1,507,931

Start Date: 10/01/98   **Term Date:** 09/30/03

Problem: Crop yields of wheat and alfalfa in the southern Great Plains are reduced by an estimated 20 to 40% each year due to disease and insect damage. Host plant resistance is the most economical and environmentally sound method of pest control. This project is directed toward the discovery and utilization of new genetic systems to control major diseases and insect pests of wheat and alfalfa. Modern techniques of genomics analysis are being used in the crop plants, disease organisms and insect pests to understand the interaction of the plants and pests at the most fundamental level. Genes controlling resistance to several diseases and insect pests are being identified and analyzed. The functions of these genes will be identified and studied to develop an understanding of how wheat and alfalfa interact with pests and pathogens to reduce crop losses. The knowledge gained is being applied to the development of new germplasms and cultivars of wheat and alfalfa.

Objectives: The main objective of this project is to increase the diversity and performance of wheat and alfalfa germplasm used in public and private breeding programs. Molecular and statistical techniques will be developed to facilitate the application of marker-assisted breeding technology to the improvement of the crops. Individual genes from wheat and alfalfa plants, and from pathogens and insect pests will be identified and studied to develop an understanding of the genes involved in the interactions of the plants and their pests. Information gained will lead to the development of plant lines with diverse arrays of genes.

Results and Impact:

1. Analysis of Plant Genes Involved in Response to Disease and Insect Attacks. Over 1500 fragments of expressed genes from wheat and alfalfa were extracted from the plants and their molecular sequence structures were determined. About 600 of these fragments were parts of genes with known function, 150 appeared to be part of disease or stress response genes. The new information gained from understanding the structure of these genes will lead to a new understanding of how resistant responses are formed in crop plants, and facilitate the identification of new resistance genes.

2. Release of Germplasm with New Resistance Gene to Leaf Rust. A hard red winter wheat germplasm, KS00WGRC44, with a new gene for resistance to leaf rust transferred from a weedy wheat relative, was developed and released to breeders. This germplasm represents a new source of leaf rust resistance in a high-yielding winter wheat background that can be easily used by breeders for cultivar development.

3. Evaluation of Pollen Migration Distances for Alfalfa. A major concern of the public related to the development of genetically modified plants is whether the pollen from those plants will contaminate seed production fields in the area. Using a naturally-occurring rare marker, we investigated the movement of pollen from alfalfa plants to surrounding fields. It was found that alfalfa pollen can be moved more than 1,000 m by pollinating insects. This distance is far more than previously reported, and indicates that absolute containment of transgenic, insect-pollinated plant pollen is highly unlikely.

4. Evaluation of Factors Impacting on the Effectiveness of Molecular Marker Use. A major research effort among scientists working in plant improvement today is associating molecular markers with traits of interest. We investigated a major hindrance to that effort encountered when working with highly diverse populations. We identified and quantified the major factors impacting upon the efficiency of the marker-trait association process. These results provide scientists with statistically validated guidelines to follow when developing molecular markers for use in plant improvement.

Goals for 2001 and 2002:

Specific tasks in 2001 will be to:

1. Identify gene markers associated with resistance to wheat pathogens Karnal bunt, leaf rust, viruses, and Fusarium head scab; make these markers available to wheat breeders and use the markers in our own breeding program.

2. Develop gene expression profiles to begin to identify the genes involved in the interaction of alfalfa and insect pests.

3. Continue the development of wheat and alfalfa germplasms.

4. Establish a molecular marker analysis program for all market classes of wheat.

5. Provide screening for resistance to Hessian fly wheat germplasm from public and private wheat breeding programs.

Specific tasks in 2002 will be to:

1. Identify the physical location of wheat genes involved in disease resistance and also begin understanding expression of these genes during various environmental conditions.

2. Identify agronomically acceptable wheat germplasm with new genes for resistance to leaf rust and powdery mildew derived from the wild relative, *Aegilops speltoides.*

3. Identify specific genes in alfalfa involved in response to feeding by insect pests.

Summary of 2000 Publications/Patents:

01. Baenziger, P.S., Moreno-Sevilla, B., Peterson, C.J., Shelton, D.R., Elmore, R.W., Klein, R.N., Baltensperger, D.D., Nelson, L.A., McVey, D.V., Watkins, J.E. and Hatchett, J.H. Registration of 'Culver' Wheat. Crop Science. 2000. v. 40 p. 862-863.

02. Brown-Guedira, G.L., Thompson, J.A., Warburton, M.L. and Nelson, R.L. Evaluation of genetic diversity of soybean introductions and North American ancestors using RAPD and SSR markers. Crop Science. 2000. v. 40 p. 815-823.

03. El Bouhssini, Mustapha, Hatchett, J.H. and Wilde, G.E. Hessian Fly (Diptera:Cecidomyiidae) Larval Survival as Affected by Wheat Resistance Alleles, Temperatures, and Larval Density. Journal Agriculture Urban Entomological. October 1999. v. 16 (4) p. 245-254.

04. Eversmeyer, M.G. and Kramer, C.L. Epidemiology of wheat leaf and stem rusts in the Central Great Plains of the USA. Annual Review Phytopathology. 2000. v. 38 p 491-513.

05. Eversmeyer, M.G. and Kramer, C.L. Dispersal of leaf rust urediniospores within a wheat canopy. Acta Phytopathologica et Entomologica Hungarica. 2000. v. 35 (1-4) p. 343-348.

06. Friebe, B., Kynast, R.G., Hatchett, J.H., Sears, R.G., Wilson, D.L. and Gill, B.S. Transfer of Wheat-Rye Translocation Chromosomes Conferring Resistance to Hessian Fly from Bread Wheat into Durum Wheat. Crop Science. 1999. v. 39 p. 1692-1696.

07. Gill, B.S,. Li, W.L., Anand, A., Fellers, J.P., Trick, H.N., Muthukrishnan, S., Lui, D.J. and Chen, P.D. Analysis of genes induced in wheat spikes upon infection with Fusarium graminearum and their manipulation to improve wheat plant resistance to Fusarium head scab disease. Proceedings of the International Symposium on wheat improvement for scab resistance. May 2000. p. 136-139.

08. Lakrod, K., Chaisrisook, C., Yongsmith, B. and Skinner, D.Z. RAPD analysis of genetic variation within a collection of red rice fungi (Monascus spp.) isolated from red rice (ang-kak) and sofu. Mycological Research. April 2000. v. 104 p. 403-408.

09. Obert, D.E., Skinner, D.Z. and Stuteville, D.L. Association of molecular markers with downy mildew resistance in autotetraploid alfalfa. Molecular Breeding. June 2000. v. 6 p. 287-294.

10. Schulte, S.J., Rider, S.D. Jr., Hatchett, J.H. and Stuart, J.J. Molecular genetic mapping of three X-linked avirulence genes, vH6, vH9 and VH13, in the Hessian fly. Genome. 1999. v. 42 p. 821-828.

11. Skinner, D.Z., Loughin, T. and Obert, D.E. Segregation and molecular marker trait associations in autotetraploid alfalfa. Molecular Breeding. June 2000. v. 6 p. 295-306.

12. Skinner, D.Z. Performance and genetic stability of alfalfa clones grown for 500 plant-years. Proceedings of the joint meeting of the 37th North American Alfalfa Improvement Conference and the American Forage and Grassland Council, July 16-19, 2000. p. 289.

13. Skinner DZ, GR Bauchan, G Auricht and S Hughes. Developing a Core Collection from a Large Annual Medicago Germplasm Collection. In: R.C. Johnson and T. Hodgkin, Editors. Core Collections for Today and Tomorrow. International Plant Genetic Resources Institute, Rome, Italy. 1999. p. 61-67.

14. St. Amand P.C., Skinner, D.Z. and Peaden, R.N. Risk of alfalfa transgene dissemination and scale-dependent effects. Theoretical Applied Genetics. 2000. v. 101 (1/2) p. 107-114.

For More Information on this Project Contact:

Dr. Daniel Z. Skinner
Telephone - (785) 532-7247
FAX - (785) 532-6167
email - dzolek@ksu.edu

CRIS 5430-21220-004-00D - Specific Cooperative Agreement

Facilitate Multiple Pest Resistant Wheat Germplasm Research

Investigators: D. Skinner and S. Ramaswamy[1]

Start Date: 09/30/98   **Term Date:** 09/30/99

Problem: Wheat in the Great Plains is attacked by a large array of diseases and insects, some of which can evolve rapidly under selection pressure applied by resistant cultivars. Economic loss to the wheat crop due to Hessian fly outbreaks can be significantly reduced by increasing the genetic diversity of the germplasm used in public and private breeding programs and by developing control strategies for those outbreaks. Molecular techniques are needed to help identify resistance genes and to help insert those resistance genes into elite cultivars. Assessment of biotypes in the natural insect population will allow use of non-chemical control strategies.

Objectives: The main objective of this project is to transfer Hessian fly resistance genes from progenitor species of wheat into agronomic backgrounds useful in breeding programs in order to increase genetic diversity.

Results and Impact: Wheat lines from collaborators in six states were screened for resistance under controlled conditions optimized to enhance the destructive ability of the insect. Over 5000 wheat lines were screened and about 850 with useful levels of resistance were identified. These partially resistant lines are being used in the development of highly-resistant wheat varieties for on-farm use; two new such varieties were released this year.

Goals for 2001 and 2002: This specific cooperative agreement will be continued to identify sources of resistance in wheat lines for variety development programs throughout the U.S. Each year, several thousand wheat lines will be screened and new sources of resistance will be identified.

2000 Publications:

01. Baenziger, P.S., Moreno-Sevilla, B., Peterson, C.J., Shelton, D.R., Elmore, R.W., Klein, R.N., Baltensperger, D.D., Nelson, L.A., McVey, D.V., Watkins, J.E. and Hatchett, J.H. Registration of 'Culver' Wheat. Crop Science. 2000. v. 40 p. 862-863.

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[1]Department of Entomology, Kansas State University

For More Information on this Project Contact:

Dr. Daniel Z. Skinner
Telephone - (785) 532-7247
FAX - (785) 532-6167
email - dzolek@ksu.edu

CRIS 5430-21220-004-00D - Specific Cooperative Agreement

Facilitate Multiple Stress Resistant Wheat and Alfalfa Germplasm Research

Investigators: D. Skinner and R. Zeigler[1]

Start Date: 07/01/00   **Term Date:** 06/30/02

Problem: Crop plants suffer from a multitude of stresses including abiotic stress. Very little is known of the basic plant functions involved in response to the stresses. Modern techniques of molecular biology and plant physiology will be used to investigate the stress response systems in wheat and alfalfa. The knowledge gained will be applied to the manipulation of plant systems to develop stress-tolerant plant lines.

Objectives: To develop molecular markers associated with specific genes conferring resistance to biotic and abiotic stress.

Results and Impact: Wheat lines have been identified that react differently to heat stress. Further investigations into the systems responsible for response and adaptation to heat and other stresses are underway. This program will contribute basic knowledge and plant materials vital to the development of high-yielding, stress tolerant crop plants.

Goals for 2001 and 2002: Individual genes associated with plant response to stress will be identified and isolated. Investigations of the interactions of the products of the genes identified will be initiated with the objectives of elucidating the pathways involved in response to specific stresses.

2000 Publications: None at this time.

For More Information on this Project Contact:

     Dr. Daniel Z. Skinner
     Telephone - (785) 532-7247
     FAX - (785) 532-6167
     email - dzolek@ksu.edu

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[1]Department of Plant Pathology, Kansas State University

WIND EROSION RESEARCH UNIT

The mission of the Wind Erosion Research Unit is to increase our understanding of wind erosion processes; develop reliable predictive tools; develop control practices; and disseminate information and technology for sustaining agriculture, protecting the environment, and conserving natural resources. The main research project for this Unit is:

CRIS - 5430-11120-005-00D   Wind Erosion Processes, Assessment, and Control

CRIS 5430-11120-002-00D

Wind Erosion Processes, Assessment, and Control

Project Leader: E. Skidmore   **Investigators:** E. Skidmore, D. Armbrust,
                                                 L. Wagner, and L. Hagen

Full-Time Scientist Equivalents (SYs): 4.0   **Net Funding to Location per Year:** $ 931,816

Start Date: 10/01/95   **Term Date:** 08/31/02

Problem: Wind erosion causes about 44 percent of the 2.13 billion tons per year of soil loss from U.S. cropland. In the Great Plains alone, about 5 million acres are moderately to severely damaged by wind erosion each year. Wind erosion physically removes the most fertile portion of the soil from the field. Some soil from damaged land enters suspension and becomes part of the atmospheric dust load. Dust obscures visibility, pollutes the air, causes automobile accidents, fouls machinery, and imperils animal and human health. Blowing soil also fills road and irrigation ditches; buries fences; reduces seedling survival and growth; lowers marketability of vegetable crops; increases susceptibility of plants to diseases; and contributes to transmission of some plant pathogens. Deposition of wind-blown sediments in drainage pathways and on water bodies significantly deteriorates water quality. Wind erosion continues as a threat to agricultural sustainability and environmental quality.

Objectives: The main goal of this project is to increase our understanding of wind erosion and dust emission processes and provide a scientific basis for development of prediction technology and control measures. Specific emphasis will be placed on the continued development of a Wind Erosion Prediction System (WEPS). This is an expert system that will provide a more reliable science-based technology for improving erosion prediction, developing soil-, climate-, and crop-specific control strategies, and for assessing erosion damage and environmental impact.

Results and Impact:

1. Field Office Testing for Implementation of WEPS. The Wind Erosion Prediction System (WEPS1.0) model was delivered to NRCS for field office evaluation. ARS scientists assisted NRCS in training selected state-level NRCS employees on the use of WEPS 1.0. This training was undertaken at 5 regional meetings: Lincoln, NE, Salt Lake City, UT, Lubbock, TX, Columbia, SC, and Des Moines, IA. The purpose of the meetings was to instruct those who will be training NRCS field office employees on the correct use and implementation of WEPS 1.0 within their agency during the next year.

2. Feedback Facilitation. To facilitate better feedback from end users to ARS developers of the Wind Erosion Prediction System (WEPS 1.0) Model an electronic network of reviewers and testers was formed. These users have email and phone access to ARS WEPS 1.0 developers to

report bugs, suggest useful enhancements, and clarify questions and concerns with the model. This has provided faster resolution of user problems within WEPS 1.0 and has helped the ARS developers stay focused on user's highest priority concerns.

Goals for 2001 and 2002:

Specific tasks for 2001 will be to:

1. Assist NRCS in implementing WEPS 1.0 by providing technical support and guidance as NRCS develops training materials and databases for WEPS 1.0. WEPS will be field tested in Western Kansas and Eastern Colorado.

2. Continue to develop commonality between WEPS 1.0 and the Water Erosion Prediction Project (WEPP) which is a similar software system designed to predict the loss of soil and the degradation of soil quality due to water erosion.

Specific tasks for 2002 will be to:

1. Assist NRCS by providing technical support as NRCS deploys WEPS 1.0 with the MOSES user interface. The MOSES interface is designed to assist WEPS and WEPP in using the same data files such as soil type etc. Customer needs will be reviewed for direction.

2. Continue to refine the development of the MOSES interface for use by NRCS.

Summary of 2000 Publications/Patents:

01. Skidmore, E.L. Wind Erosion from Accidently Burned Conservation Reserve Land. International Geophysical Union Commission on Land Degradation and Desertification. Perth, Australia, September 1999.

02. Hagen, L.J., Zobeck, T.M. and Skidmore, E.L. Modeling surface aggregate status for wind erosion prediction. Agronomy Abstracts, American Society of Agronomy, Madison, WI. 1999. p.279.

03. Zobeck, T., Hagen, L.J., Stout, J.E. and Skidmore, E.L. Modeling soil micro-relief for wind erosion modeling. American Society of Agronomy, Madison, WI. 1999. Abst. p.281.

04. Skidmore, E.L. and Liu, Cathy. Estimating random roughness in the field. International Tillage Research Organization. ISTRO 2000 Conference Book of Abstracts. 2000.

05. Skidmore, E.L., Huang, X. and Tatarko, J. Soil Quality as Influenced by Wind. Wind Erosion. International Erosion Control Association 31st Annual Conference. Palm Springs, CA. 2000.

06.   Skidmore, E.L. and Hagen, L.J. Air Quality as Influenced by Wind Erosion: Research at USDA-ARS, Manhattan, KS. Air Quality National Program Workshop. Sacramento, CA. January 2000.

07. Retta, A., Hagen, L.J., Wagner, L.E., Armbrust, D.V. and Skidmore, E.L. Yield Adjustment Factor for WEPS (Wind Erosion Prediction System). Modeling for the 21st Century: Thirty Years of Crop Modeling, Temple, TX. 6-8 March 2000.

08. Dregne, H.E. and Skidmore, E.L. Global land degradation: Extend and impact of soils. J. Soil and Water Conserv. Soc. 55:402, 2000.

09. Wagner, L.E. Modeling of tillage processes in the Wind Erosion Prediction System (WEPS). ISTRO -2000, 15th Conference of the International Soil Tillage Research Organigation, Fort Worth, Texas. 2-7 July 2000

For More Information on this Project Contact:

Dr. Ed Skidmore
Telephone - (785) 532-6726
FAX - (785) 532-6528
email - skidmore@weru.ksu.edu

CRIS 5430-11120-005-00D - Specific Cooperative Agreement

Development of a Tillage System to Prevent Pulverizing Erosion

Investigators: L. Hagen and S. Podsiadlowski[1]

Start Date: 10/01/96   **Term Date:** 07/31/00

Problem: Farmers in both the U.S. and Poland generally operate on low profit margins. Thus, damage to seedlings and depletion of soil nutrients by wind erosion can easily make farming unprofitable in years when erosion is significant. Wind speeds are lower in Poland than in the Great Plains of the U.S. Nevertheless, wind erosion on sandy soils in Poland occurs about one year in three with the conventional tillage system.

Objectives: The project objective is to design and evaluate a tillage system for sandy loam soils that reduces wind erosion in Poland.

Results and Impact: A project to develop wind erosion-resistant seed beds for sugar beets and small grains on sandy loam soils in Poland was completed. Results showed that using a single-pass integrated tillage system greatly reduced potential wind erosion when compared to conventional multi-pass systems used for seed bed preparation and sowing. In addition, the integrated tillage system used about 30 percent less fuel than the conventional system. As economic conditions allow, land managers are implementing the integrated system in Poland and other Eastern European countries on soils that are susceptible to wind erosion.

Goals for 2001: This project is completed.

2000 Publications:

01. Padsiadlowski, S. and Hagen, L.J. Tan integrated tillage system to prevent pulverization and wind erosion of sandy soils. Proc. 15th Conference of the International Soil Tillage Residue Organization, July 2-7, 2000, Fort Worth, TX.

For More Information on this Project Contact:

Dr. Larry Hagen
Telephone - (785) 532-6785
FAX - (785) 532-6528
email - hagen@weru.ksu.edu

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[1]University of Pozan, Poland

CRIS 5430-11120-005-00D - Specific Cooperative Agreement

Educational Tools for Wind Erosion Control

Investigators: E. Skidmore, J. Tatarko[1], and G. Tibke[2]

Start Date: 12/01/97   **Term Date:** 11/30/02

Problem: Nearly sixty years after the Dust Bowl ended, wind erosion continues to threaten the sustainability of our nations' natural resources. The Natural Resources Conservation Service (NRCS) is the primary agency through which research and knowledge about wind erosion is directly transferred to the land manager. This agency has expressed a need for training materials in the principles and control of wind erosion.

Objectives: The project goal is to develop educational materials for NRCS, producers, and other conservation partners in the physical principles, processes, and causes of wind erosion and in the design and implementation of farming systems for wind erosion control. The primary product of this project will be a video. A web version will also be produced.

Results and Impact: The video script was completed and delivered to the senior producer/director at Kansas State University for completion of the video.

Goals for 2001: Both the video and the web site will be completed.

2000 Publications: None at this time.

For More Information on this Project Contact:

>   Dr. Ed Skidmore
>   Telephone - (785) 532-6726
>   FAX - (785) 532-6528
>   email - skidmore@weru.ksu.edu

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[1]Department of Agronomy, Kansas State University

[2]USDA-NRCS, attached to WERU in Manhattan, KS

CRIS 5430-11120-005-00D - Cooperative Research and Development Agreement

Wind Erosion Assessment and Control

Investigators: E. Skidmore, X. Huang[1], F. Fox, and L. Wagner

Start Date: 09/25/98   **Term Date:** 09/24/03

Cooperator: Natural Resources Conservation Service

Problem: Wind erosion of soil continues as a major environmental and agricultural problem. It degrades the land resources, threatens the sustainability of agriculture, and pollutes air and water. To reduce soil erosion on marginal cropland, the U.S. Congress established the Conservation Reserve Program (CRP). The CRP was highly successful in reducing wind erosion. But now as many of the contracts are expiring, the Natural Resources Conservation Service (NRCS) recognizes new challenges and supports high priority wind erosion research.

Objectives: Project objectives are to determine the change in soil erodibility and other soil quality measures resulting from CRP, to develop a device to measure standing crop residues after harvest using laser technology, and to develop modular soil erosion systems (MOSES) common interface for water and wind erosion models used by NRCS.

Results and Impact: Various soil properties were measured from continuously cropped land and nearby land that had been in the CRP program for ten years and compared. We found that land that had been in CRP was less susceptible to erosion compared to continuously cropped land. Land managed in CRP tends to improve some soil properties.

Quick, accurate and repeatable measurement of standing plant residue is necessary for the development of land use practices which minimize the potential for a soil to erode by wind. Experiments were set up and executed at WERU to test the concept of a laser scanning system to measure count standing plant residue stems and their aggregate height and width and construction of a field portable device was initiated. Experimental data were obtained, analyzed and reported and hardware assembled for a field portable device. Requests for information indicate that there is interest in both the concept and the method among cropping system researchers and potential impact with tillage systems research.

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[1]Kansas State University

Goals for 2001 and 2002:

Specific tasks in 2001 will be to:

1. Continue to monitor the spatial variation of soil properties over time for land going into Conservation Reserve Program(CRP), coming-out of CRP, and never in CRP. Prepare interim reports (publications).

Specific tasks in 2002 will be to:

1. Continue to monitor the spatial variation of soil properties over time for land going into CRP, coming-out of CRP, and never in CRP.

2000 Publications:

01. Skidmore, E.L., Huang, X. and Tibke, G.L. Aggregate status as influenced by CRP. Agronomy Abstracts, American Society of Agronomy. November 1999. p. 174

02. Huang, X., Skidmore, E.L. and Tibke, G. Change in soil quality indicators resulting from CRP. Agronomy Abstracts, American Society of Agronomy. November 1999. p.173.

03. Fox, F.A. and Wagner, L.E. A Laser Distance Based Method for Measuring Standing Residue. ISTRO-2000, 15th Conference of the Int. Soil Till. Res. Org., Fort Worth, TX. 2-7 July 2000

For More Information on this Project Contact:

> Dr. Ed Skidmore
> Telephone - (785) 532-6726
> FAX - (785) 532-6528
> email - skidmore@weru.ksu.edu

CRIS 5430-11120-005-00D - Cooperative Research and Development Agreement

Wind Erosion Model for Military Lands

Investigators: E. Skidmore, R. Nelson[1], and A. Anderson[2]

Start Date: 09/25/98   **Term Date:** 09/24/03

Cooperator: U.S. Department of the Army

Problem: Military training and testing often damages the fragile natural ecosystem on which this training occurs. Vegetation is destroyed and surface conditions are altered by training exercises. The ability of lands to accommodate and sustain the military mission has been identified as a high priority DoD/Tri-Service user requirement.

Objectives: The goal for this project is to provide the needed information to develop a more accurate measure of the Army Training and Testing Area Carrying Capacity (ATTACC) methodology. Previous work using only estimations of water erosion resulted in an under-estimation of land deterioration and an over-estimation of carrying capacity.

Results and Impact: The ARS-Wind Erosion Research Unit in collaboration with Tierra Data Systems, Marine Corps Air Ground Command Center, and Army Corps of Engineers has started a validation study of WEPS for military needs. Air-borne sediment traps were installed at five positions along a 100 meter transect at five strategic locations on the Marine Corps Air Ground Command Center, Twenty-nine Palms, CA. Implementation of WEPS to military needs will facilitate greatly the management of training lands for improved personnel safety and conservation of natural resources.

Goals for 2001 and 2002:

Specific tasks in 2001 will be to:

1. Conduct field studies to address deficiencies in the model when applied to military lands.

Specific tasks in 2002 will be to:

1. Extend the management component of the most applicable wind erosion model to include military land use activities (i.e. wheeled and tracked vehicle traffic) and common military land maintenance and repair practices.

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[1]Kansas Industrial Extension Service, Kansas State University
[2]Department of the Army

2000 Publications:

01. Nelson, R., Anderson, A. B. and Skidmore, E. L. Evaluation of Wind Erosion Models for Use on Military Training Lands. Proceedings of Conference 31. International Erosion Control Association, February 2000. p 387-388.

02. Skidmore, E.L., Anderson, A. B., Nelson, R. and Gebhart, D. Wind erosion models for managing lands: past and future. Agronomy Abstracts, American Society of Agronomy, Madison, WI, 2000. p. 11.

For More Information on this Project Contact:

Dr. Ed Skidmore
Telephone - (785) 532-6726
FAX - (785) 532-6528
email - skidmore@weru.ksu.edu

CRIS 5430-11120-005-00D - Cooperative Research and Development Agreement

Develop Technology for Emission Inventories of PM-10 and PM-2.5 Generated by Wind Erosion

Investigators: L. Hagen

Start Date: 10/99   **Term Date:** 09/00

Cooperator: Environmental Protection Agency

Problem: The Environmental Protection Agency (EPA) is required to provide annual inventories of emissions of fine particles (PM-10 and PM-2.5) that are regulated as health hazards. In many areas, wind erosion is one of the major sources of fine particles and must be included in the EPA inventory.

Objectives: The objective of this research is to extend the Wind Erosion Prediction System (WEPS) technology developed by USDA scientists with additional databases and other enhancements, so that EPA can apply WEPS in developing their inventory of fine particles generated by wind erosion for each county in the U.S.

Results and Impact: Soil samples collected from nine western states were analyzed in the laboratory to determine their ability to generate fine particles during simulated wind erosion processes. Significant differences were detected among various soil textures in their ability to produce PM-10. These experimental results will be incorporated to improve the technology used to simulate PM-10 emissions from various soils.

Goals for 2001:

1. WEPS model enhancements and additional databases will be developed to provide technology to improve fine particulate emissions estimates at the county level in the U.S. We anticipate developing fine particle emissions inventories for a few test counties during this research..

2000 Publications:

01. Puma, M.C., Maghirang, R.G., Hosni, M.H., Hagen, L.J. Modeling of dust concentration distribution in a simulated swine room under non-isothermal conditions. Trans. Amer. Soc. Agric. Engin.1999. v. 42(6) p. 823-1832.

02. Hagen, L.J. Analyses of PM-10 and PM-2.5 generation potential of soil samples collected in nine Western States. Technical Report submitted to U.S. EPA EPA/IAG Project No. DW1293826-01-0, 2000. p. 1-20.

For More Information on this Project Contact:

Dr. L. Hagen
Telephone - (785) 532-6785
FAX - (785) 532-6528
email - hagen@weru.ksu.edu

PERSONNEL DIRECTORY

Last Name	First Name	Work Phone Area Code -785	Email Address
ALEXANDER	John	776-2727	jal6464@ksu.edu
ANDERES	Jeffery	537-5500	janderes@gmprc.ksu.edu
ANDERSON	Sheri	776-2766	anderson@gmprc.ksu.edu
ARMBRUST	Dean	532-6822	armbrust@weru.ksu.edu
ARTHUR	Frank	776-2783	arthur@gmprc.ksu.edu
AYALA	Jorge	776-2720	ayalaj@ksu.edu
BAKER	James	776-2785	baker@gmprc.ksu.edu
BARNETT	Brian	776-2765	barn@gmprc.ksu.edu
BARNETT	Justin	776-2747	whoha21@hotmail.com
BEAN	Scott	776-2764	scotbean@gmprc.ksu.edu
BECHTEL	Don	776-2713	don@gmprc.ksu.edu
BEEMAN	Richard	776-2710	beeman@gmprc.ksu.edu
BELLINGER	Brian	532-4718	brianbellinger@yahoo.com
BRABEC	Dan	776-2731	dan@gmprc.ksu.edu
BROWN-GUEDIRA	Gina	532-7260	gbg@ksu.edu
CALEY	Margo	776-2755	margo@gmprc.ksu.edu
CAMPBELL	James	776-2717	campbell@gmprc.ksu.edu
CASADA	Mark	776-2758	casada@gmprc.ksu.edu
CASSITY	Terry	776-2723	tbc@gmprc.ksu.edu
CHANDRA	Sahana	776-2764	ssc7803@ksu.edu
CHAPMAN	Mandy	776-2716	mandy_j_chapman@yahoo.com
CHRISTIAN	Mike	532-2280	mchristi@oznet.ksu.edu
CHUNG	Okkyung Kim	776-2703	okchung@gmprc.ksu.edu
CRAYCRAFT	Sherry	537-5512	arsipm@yahoo.com
CROFOOT	Cheryl	532-6168	chc@alfalfa.ksu.edu
DALLUGE	Glen	776-2760	ggd@ksu.edu
DICKINSON	Jeri	776-2716	jed3325@ksu.edu
DOTSON	Abby	776-2773	ald8484@kau.wsu
DOVER	Eric	776-2764	edover@gmprc.ksu.edu
DOWELL	Floyd	776-2753	fdowell@gmprc.ksu.edu
DOWNING	John	776-2761	johnd@gmprc.ksu.edu
DOYUNGAN	Zaldy	776-2781	doyungan@ksu.edu
EADES	Kelly	776-2754	keades@gmprc.ksu.edu
FABRICK	Jeffrey	776-2785	fabrick@gmprc.ksu.edu
FAY	Kevin	776-2777	kevin@gmprc.ksu.edu
FELLERS	John	532-2367	jpf@alfalfa.ksu.edu

Last Name	First Name	Work Phone Area Code -785	Email Address
FLINN	Paul	776-2707	flinn@gmprc.ksu.edu
FOX, JR.	Fred	532-6694	fredfox@weru.ksu.edu
FRIESEN	Kenlee	776-2756	friesen@gmprc.ksu.edu
GRESENS	Joanne	776-2733	joanne@gmprc.ksu.edu
GRUNEWALD	Marsha	776-2757	marsha@gmprc.ksu.edu
GU	Yiwen (William)	532-7173	ywgu@weru.ksu.edu
GUGLIELMINO	Maria	537-5506	mgugliel@vet,ksu.edu
GUNN	Brandon	532-2767	poppa_ice@hotmaul.com
HAAS	Sue	776-2767	haas@gmprc.ksu.edu
HADEN	Zina	776-2775	zina@gmprc.ksu.edu
HAGEN	Larry	532-6785	hagen@weru.ksu.edu
HAGSTRUM	David	776-2718	hagstrum@gmprc.ksu.edu
HAMMEL	Richard	776-2784	hammel@gmprc.ksu.edu
HARTZER	Kris	537-5580	hartz@ksu.edu
HATCHETT	Jim	532-4719	jhatchet@oz.oznet.ksu.edu
HAYS	Dirk	532-7116	dhays@alfalfa.ksu.edu
HILL-AMBROZ	Kristi	532-2767	kha@alfalfa.ksu.edu
HOERNEMANN	Courtenay	776-2724	hoern@gmprc.ksu.edu
HOTTMAN	Alan	776-2722	hottman@gmprc.ksu.edu
HOWARD	Ralph	776-2706	howard@gmprc.ksu.edu
HOWELL	Kimberly	532-3560	khowell@plantpath.ksu.edu
HUANG	Xuewen	532-7174	huangxw@weru.ksu.edu
HUBBARD	John	776-2750	john@gmprc.ksu.edu
HUSE	Eugene	776-2723	ehuse@gmprc.ksu.edu
JEFFERIES	Paul	532-6090	pwj7676@ksu.edu
JEFFERIS	Adam	532-3560	alj5537@ksu.edu
JOHNSON	Shirley	776-2726	shirley@gmprc.ksu.edu
KOELTZOW	Donald	776-2702	dek@gmprc.ksu.edu
KOHAKE	David	532-6916	djk@weru.ksu.edu
KRAMER	Bud	532-6168	
KRAMER	Karl	776-2711	kramer@gmprc.ksu.edu
KUHL	Brent	776-2723	kuhl@gmprc.ksu.edu
LIDDELL	Elaine	776-2704	liddell@gmprc.ksu.edu
LOOKHART	George	776-2736	george@gmprc.ksu.edu
LORD	Jeffrey	776-2705	lord@gmprc.ksu.edu
LORENZEN	Marce'	776-2716	marce@ksu.edu
LU	Yimin	776-2797	ylu1250@ksu.edu
LYNE	Rhonda	776-2788	rhonda@gmprc.ksu.edu
MAGHIRANG	Elizabeth	776-2721	emaghira@gmprc.ksu.edu

Last Name	First Name	Work Phone Area Code -785	Email Address
MARN	Barb	776-2738	gjm@gmprc.ksu.edu
MARTIN	Charles (Chaz)	776-2730	chaz@gmprc.ksu.edu
MATHEWSON	Sandy	776-2701	sandy@gmprc.ksu.edu
MATTHEWS	Angie	532-7244	amathews@plantpath.ksu.edu
MCANARNEY	Dan	532-3713	dkm@weru.ksu.edu
MCLAUGHLIN	Laura	776-2744	milling@gmprc.ksu.edu
MORGAN	Jared	776-2744	jmm9464@ksu.edu
MORGAN	Thomas	776-2715	morgan@gmprc.ksu.edu
MOWERY	Sharon	776-2724	smowery@oz.oznet.ksu.edu
MULLEN	Michael	776-2782	mullen@gmprc.ksu.edu
OHM	Jae	776-2708	jay@gmprc.ksu.edu
OLIVER	Jimmie	776-2737	jno@gmprc.ksu.edu
OPPENLANDER	Aileen	776-2739	alo@gmprc.ksu.edu
OPPERT	Brenda	776-2780	bso@ksu.edu
PARK	Seok-Ho	776-2708	seokho@gmprc.ksu.edu
PARKER	Charles	532-6242	cep@alfalfa.ksu.edu
PASIKATAN	Melchor	537-5575	choypc@gmprc.ksu.edu
PATTON	Larry	532-6168	
PEREZ-MENDOZA	Joel	537-5570	perez@gmprc.ksu.edu
PHILLIPS	Mendy	776-2773	marissa@ksu.edu
PICKARD	Murray	776-2729	mpickard@gmprc.ksu.edu
RAM	M.S.	776-2728	ramms@gmprc.ksu.edu
REDMON	Ann	776-2772	redmon@gmprc.ksu.edu
RETTA	Amare	532-7164	retta@weru.ksu.edu
ROSS VARDEMAN	Tawanna	532-2767	tgrv@alfalfa.ksu.edu
ROTTINGHAUS	Charles	776-2773	crott@hotmail.com
ROUSSER	Robert	776-2746	bobr@gmprc.ksu.edu
RUNNION	Carrie	537-5506	cer3030@ksu.edu
RUST	William	532-6233	wjr@weru.ksu.edu
RYLEE	Mike	776-2799	rylee@gmprc.ksu.edu
RYSER	Amy	532-3560	alr5798@ksu.edu
SAGER	Chad	776-2716	cas4444@ksu.edu
SAUER	David	776-2725	dave@gmprc.ksu.edu
SAYASLAN	Abdulvahit	776-2774	ats@ksu.edu
SCHRADER	Marsha	532-6495	marsha@weru.ksu.edu
SEABOURN	Brad	776-2751	brad@gmprc.ksu.edu
SEITZ	Larry	776-2735	larry@gmprc.ksu.edu
SHACK	Troy	776-2723	kett@gmprc.ksu.edu
SHOGREN	Merle	776-2740	merle@gmprc.ksu.edu

Last Name	First Name	Work Phone Area Code -785	Email Address
SKIDMORE	Ed	532-6726	skidmore@weru.ksu.edu
SKINNER	Daniel	532-7247	dzolek@ksu.edu
SMITH	Joe	776-2723	jps@gmprc.ksu.edu
SNOW	Kathy	776-2781	kjs57572ksu.edu
SPEIRS	Roy	776-2772	
STEELE	Jana	776-2749	jls9887@ksu.edu
STONE	Aaron	776-2744	milling@gmprc.ksu.edu
TATARKO	John	532-6720	jt@weru.ksu.edu
THRONE	James	776-2796	throne@gmprc.ksu.edu
TIBKE	Gary	532-7163	tibke@weru.ksu.edu
TILLEY	Denis	776-2747	dtilley@gmprc.ksu.edu
TILLEY	Michael	776-2759	mtilley@gmprc.ksu.edu
TRUMAN	Colleen	532-4718	ctruman@alfalfa.ksu.edu
VAN DONK	Simon	532-6694	sdonk@weru.ksu.edu
VARDEMAN	Jade	776-2752	vardeman@gmprc.ksu.edu
WAGNER	Larry	532-6807	wagner@weru.ksu.edu
WALKER	Duane	776-2732	dew@gmprc.ksu.edu
WANG	Ning	537-2745	wangn@ksu.edu
WATERS	Brenda	776-2714	waters@gmprc.ksu.edu
WHITE	Megan	776-2716	megw@ksu.edu
WILSON	Jeff	776-2763	jdw@gmprc.ksu.edu
WOEMMEL	Jeff	776-2763	dew2777@ksu.edu
XIAO	Susan	776-2755	
XIE	Feng	537-5581	fxi9437@ksu.edu
ZHANG	Hong	776-2797	zhang@ksu.edu
ZHANG	Kui	776-2799	kzhang@ksu.edu
ZUERCHER	Michele	537-5580	zuercher@gmprc.ksu.edu